Deliverable 6.4
Final results: Impacts on traffic safety

Version number: Version 1.1
Dissemination level: PU
Lead contractor: VOLVO
Due date: 10.06.2012
Date of preparation: 21.11.2012
Authors
Lucas Malta (VOLVO)
Mikael Ljung Aust (VCC)
Freek Faber (TNO)
Barbara Metz (IZVW)
Guillaume Saint Pierre (IFSTTAR)
Mohamed Benmimoun (IKA)
Roland Schäfer (Ford)

Contributors
Dan Gustafsson (VCC)
Andreas Pütz (IKA)
Marco Dozza (CHALMERS)
Dmitrii Zholud (CHALMERS)

This deliverable has been compiled by the above authors, but it is a summary of individual contributions from many other authors as indicated in the relevant cited references. All results are scientific findings which are only valid inside the statistical assumptions and other limits of application. All findings have to be considered with the associated range of significance. The affiliation of the authors with any organization involved in this project does not indicate that those organizations endorse all the findings contained within this report.

Project Coordinator
Aria Etemad
Ford Research & Advanced Engineering Europe

Phone: +49 241 9421 246
Fax: +49 241 9421 301
Email: aetemad1@ford.com

Ford Forschungszentrum Aachen GmbH
Suesterfeldstr. 200
D-52072 Aachen
Germany

Copyright: euroFOT Consortium 2012
## Revision and history chart

<table>
<thead>
<tr>
<th>Version</th>
<th>Date</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>2011-11-30</td>
<td>Created by Lucas Malta.</td>
</tr>
<tr>
<td>0.2</td>
<td>2011-12-14</td>
<td>Input from Freek Faber and Mohamed Benmimoun.</td>
</tr>
<tr>
<td>0.3</td>
<td>2012-04-02</td>
<td>Lucas Malta: included hypothesis templates for SL+CC, BLIS, LDW, navigation system, and RMA received from all partners.</td>
</tr>
<tr>
<td>0.4</td>
<td>2012-04-07</td>
<td>Lucas Malta: included chapter on function review.</td>
</tr>
<tr>
<td>0.5</td>
<td>2012-04-20</td>
<td>Lucas Malta: included combined G1-SE VMC’s chapter on ACC+FCW with input from Mohamed Benmimoun, Andreas Pütz, and Mikael Ljung Aust.</td>
</tr>
<tr>
<td>0.6</td>
<td>2012-04-24</td>
<td>Lucas Malta: added chapter on lessons learned with input from all partners.</td>
</tr>
<tr>
<td>0.7</td>
<td>2012-04-27</td>
<td>Roland Schäfer /Mikael Ljung Aust: added chapters on target crash population, impact on the national level, and up-scaling to EU-27</td>
</tr>
<tr>
<td>0.8</td>
<td>2012-05-02</td>
<td>Lucas Malta: added conclusion with input from Mikael Ljung Aust, Barbara Metz, Mohamed Benmimoun, and Freek Faber.</td>
</tr>
<tr>
<td>0.9</td>
<td>2012-05-02</td>
<td>Lucas Malta: added executive summary with input from Mikael Ljung Aust, Mohamed Benmimoun, and Freek Faber.</td>
</tr>
<tr>
<td>0.9 Rev.</td>
<td>2012-05-15</td>
<td>Peer review by M. Kunert /Bosch</td>
</tr>
<tr>
<td>0.9 Rev.</td>
<td>2012-05-16</td>
<td>Peer review by Kerry Malone /TNO</td>
</tr>
<tr>
<td>0.9 Rev.</td>
<td>2012-05-20</td>
<td>Peer review by Carol Flannagan /UMICH</td>
</tr>
<tr>
<td>0.9 Rev.</td>
<td>2012-05-21</td>
<td>Peer review by Andrew Johnson /Ford</td>
</tr>
<tr>
<td>0.9 Rev.</td>
<td>2012-06-01</td>
<td>Reviewer comments addressed</td>
</tr>
<tr>
<td>0.9 Rev.</td>
<td>2012-06-08</td>
<td>Mikael Ljung Aust, minor corrections and updates added</td>
</tr>
<tr>
<td>1.0</td>
<td>2012-06-15</td>
<td>Revision, updates, layout check: Tables, References, Hypotheses moved to Annex, Headline adaptations</td>
</tr>
<tr>
<td>1.01</td>
<td>2012-11-09</td>
<td>Mikael Ljung Aust (VCC), Mohamed Benmimoun (Ika)</td>
</tr>
<tr>
<td>1.1</td>
<td>2012-11-19</td>
<td>Final layout check EICT</td>
</tr>
</tbody>
</table>
Table of contents

Revision and history chart ........................................................................................................ iii
Table of contents ........................................................................................................................ iv
Table of figures .......................................................................................................................... vi
Table of tables .......................................................................................................................... viii
Executive Summary ................................................................................................................. 1
1 Introduction ............................................................................................................................ 4
   1.1 Background ...................................................................................................................... 4
   1.2 Impact Assessment .......................................................................................................... 5
   1.3 Relationship with other sub-projects and deliverables in euroFOT ................................... 8
2 A short review of the safety impact methodology ................................................................ 10
3 A short review of studied functions ....................................................................................... 15
   3.1 ACC+FCW ...................................................................................................................... 15
   3.2 LDW(+IW for cars) ........................................................................................................ 16
   3.3 Speed Limiter and Cruise Control (SL+CC) ................................................................... 18
   3.4 Navigation System ......................................................................................................... 19
   3.5 BLIS ................................................................................................................................. 21
   3.6 CSW ................................................................................................................................. 21
4 Identifying changes in safety-related measures between baseline and treatment .................. 23
   4.1 Hypotheses results for cars ........................................................................................... 23
      4.1.1 ACC+FCW ............................................................................................................... 23
      4.1.2 LDW+IW ................................................................................................................. 33
      4.1.3 Speed Limiter and Cruise Control (SL+CC) .......................................................... 34
      4.1.4 Navigation System ................................................................................................. 37
      4.1.5 BLIS ........................................................................................................................ 41
      4.1.6 Risk Matrix Approach (RMA) ............................................................................... 42
   Hypotheses results for trucks .............................................................................................. 47
      4.1.7 ACC+FCW ............................................................................................................... 47
      4.1.8 LDW ........................................................................................................................ 53
      4.1.9 Risk Matrix Approach (RMA) ............................................................................... 55
5 Defining the target crash population ...................................................................................... 59
   5.1 ACC+FCW ...................................................................................................................... 61
   5.2 LDW+IW ........................................................................................................................ 63
   5.3 Speed Limiter and Cruise Control (SL+CC) ................................................................... 65
   5.4 Blind Spot Information System (BLIS) ......................................................................... 65
   5.5 Navigation Systems ........................................................................................................ 66
6 Impact on a national level ..................................................................................................... 67
7 Up-scaling of euroFOT safety impacts to EU-27 ................................................................. 70
8 Discussion and conclusion ................................................................................................... 77
9 Lessons learned and future recommendations ................................................................... 81
References ............................................................................................................................... 84
Annex 1: Hypotheses results for cars: ACC+FCW ................................................................. 87
Annex 2: Hypotheses results for cars: LDW+IW ................................................................. 110
Annex 3: Hypotheses results for cars: Speed Limiter Cruise Control (SL+CC) ...................... 128
Annex 4: Hypotheses results for cars: Navigation System .................................................... 154
Annex 5: Hypotheses results for cars: BLIS ........................................................................... 166
Annex 6: Hypotheses results for trucks: ACC+FCW ........................................................... 168
Annex 7: Hypotheses results for trucks: LDW ................................................................. 188
Annex 8: Video annotation in euroFOT ............................................................................ 199
Annex 9: List of abbreviations ...................................................................................... 202
Annex 10: Overview of safety-related measures ......................................................... 203
Table of figures

Figure 1: Overview of the safety impact process and the data sources used ........................................ 6
Figure 2: Traffic density comparison in filtered baseline and treatment for ACC+FCW (cars in Germany) .................................................................................................................................25
Figure 3: Traffic density comparison in filtered baseline and treatment for ACC+FCW (cars in Sweden) ........................................................................................................................................25
Figure 4: ACC+FCW usage for cars under different situational variables ........................................ 27
Figure 5: Overall benefit of ACC+FCW on motorways (passenger cars) ........................................ 28
Figure 6: Overall benefit of ACC+FCW on rural roads (passenger cars) ......................................... 28
Figure 7: Overall benefit of ACC+FCW on urban roads (passenger cars) ........................................ 29
Figure 8: Harsh braking events in baseline and treatment with consideration of ACC and FCW activation phases (passenger cars) ........................................................................................................30
Figure 9: Number of FCW warnings in baseline and treatment on motorways (passenger cars) ........30
Figure 10: Traffic density comparison in filtered baseline and treatment for LDW+IW (cars) ............33
Figure 11: Overall benefit of LDW (passenger cars) ......................................................................... 34
Figure 12: Odds ratios corresponding to the event “SL is active” (resp. “CC is active”) for different binary situational variables ........................................................................................................35
Figure 13: Proportion of trips with active navigation system separate for familiarity of route and trip length ..................................................................................................................................................37
Figure 14: Risk Modification Factor per situation treatment versus baseline ..................................44
Figure 15: Risk Modification Factor per situation ACC on versus baseline .................................. 45
Figure 16: Cumulative sum of vehicle speed 10m before junction .................................................. 48
Figure 17: Traffic density comparison in filtered baseline and treatment for ACC+FCW (trucks) .......49
Figure 18: ACC+FCW usage for trucks under different situational variables .................................. 50
Figure 19: Overall benefit of ACC+FCW on motorways (trucks) .................................................... 50
Figure 20: Number of FCW warnings in baseline and treatment on motorways for different posted speeds (trucks) ........................................................................................................................................52
Figure 21: Traffic density comparison in filtered baseline and treatment for LDW (trucks) .............. 54
Figure 22: Overall benefit of LDW (trucks) ....................................................................................... 55
Figure 23: Risk Modification Factor per situation treatment versus baseline .................................. 57
Figure 24: Risk Modification Factor per situation ACC ON versus baseline ................................. 58
Figure 25: Comparison of casualty shares in road accidents by traffic participation and injury severity ..................................................................................................................................................60
Figure 26: Example of filtering GIDAS cases to determine relevant shares of accidents and casualties ..................................................................................................................................................61
Figure 27: Qualitative illustration of filter process of relevant accidents and casualties for euroFOT safety impacts .............................................................................................................................................73
Figure 28: Number of Time-headway under 0.5s per 100km ............................................................ 88
Figure 29: Percentage of Time-headway under 0.5s. ..............................89
Figure 30: Average speeds in baseline and treatment. ..............................92
Figure 31: Number of incidents based on vehicle kinematics per 100km (passenger cars). ..............................94
Figure 32: Number of incidents based on video annotation per 100km (passenger cars). ....95
Figure 33: Number of high decelerations per 100 driven km (passenger cars). ........97
Figure 34: Relative risk of strong braking reactions (passenger cars)............................98
Figure 35: Average THW in baseline and treatment (passenger cars).......................100
Figure 36: Accelerator pedal usage (given ACC is active) change per driver ................104
Figure 37: Median lateral offset (passenger cars).................................................113
Figure 38: Mean Steering Wheel Angle. ..............................................................114
Figure 39: SL effect on average speed per speed limit ...........................................129
Figure 40: CC effect on average speed per speed limit ............................................142
Figure 41: Having SRS effect on average speed per speed limit ................................153
Figure 42: Incident frequency at intersections .......................................................156
Figure 43: Proportion of time with critical THW (left) and critical TTC (right) split for road type .................................................................159
Figure 44: Proportion of time with critical time to line crossing (left) and number of lane exceedances per hour (right) separate for road type .................................................................161
Figure 45: Influence of condition on number of hard braking events per hour separate for road type .................................................................163
Figure 46: Influence of condition on number of hard accelerations per hour separate for road type .................................................................165
Figure 47: Risk of critical THW in baseline and treatment......................................169
Figure 48: Average speed in baseline and treatment .............................................171
Figure 49: Number of incidents based on vehicle kinematics per 100km (trucks). ........173
Figure 50: Number of incidents based on video annotation per 100km (trucks). ........174
Figure 51: Number of high decelerations per 100 driven km (trucks). .................176
Figure 52: Relative risk of strong braking reactions (trucks). ..............................177
Figure 53: Average THW in baseline and treatment (trucks)...............................179
Figure 54: Accelerator pedal usage (given ACC is active) change per driver (trucks) ....185
Figure 55: Median lateral offset (trucks) ..............................................................189
**Table of tables**

Table 1: Summary of the impact of ACC+FCW ................................................................. 2
Table 2: Impact of different functions in the literature .................................................. 7
Table 3: Estimated benefit of ACC+FCW (cars) .............................................................. 32
Table 4: Proportion of time driving with navigation system active on urban and rural roads. .. 38
Table 5: Overall benefit of the Navigation System ......................................................... 39
Table 6: Benefit of the Navigation System with separate analyses for familiar and unfamiliar trips .................................................................................................................. 40
Table 7: Proportion of travel time spent on familiar trips for urban and rural roads. .......... 40
Table 8: Risk Modification Factor and mileage per situation for treatment versus baseline ... 43
Table 9: Risk Modification Factor and mileage per situation for treatment ACC ON versus baseline ................................................................. 45
Table 10: Estimated benefit of ACC+FCW (trucks) .......................................................... 53
Table 11: Risk Modification Factor and mileage per situation for treatment versus baseline .... 56
Table 12: Risk Modification Factor and mileage per situation for treatment ACC ON versus baseline .................................................................................................................. 57
Table 13: Average annual average accident frequencies and shares of the overall crash population for ACC+FCW relevant longitudinal crashes in Sweden and Germany ............... 62
Table 14: Accident target groups for ACC+FCW - relevant longitudinal crashes involving trucks in Germany and UK ................................................................. 63
Table 15: Average annual accident frequencies for LDW+IW relevant to lane departure initiated crashes for Sweden ................................................................. 64
Table 16: Average annual accident frequencies for LDW+IW relevant lane departure initiated crashes for UK .................................................................................................. 64
Table 17: Average annual accident frequencies for BLIS relevant crashes for Sweden ................................................................. 65
Table 18: Usage and predicted benefit range for ACC+FCW in cars ................................ 67
Table 19: The predicted safety impact of ACC+FCW for cars based on German and Swedish data .......................................................................................................................... 67
Table 20: Usage and predicted benefit range for ACC+FCW in Trucks ............................ 68
Table 21: The predicted benefit of ACC+FCW for trucks based on German and British data. .......................................................................................................................... 68
Table 22: Road fatalities in EU-27: car occupants & distribution over road type .............. 71
Table 23: All road fatalities and injury accidents and involved car occupants in 2008 ........ 72
Table 24: EU-27 target population in terms of relevant accidents/casualties for ACC+FCW cars .......................................................................................................................... 74
Table 25: ACC+FCW cars - results from impact assessment of safety-related hypothesis per road type .......................................................................................................................... 74
Table 26: The estimated safety impact of ACC+FCW for passenger cars based on EU-27 accident data .......................................................................................................................... 74
Table 27: Generic share on EU-27 accidents/casualties relevant for ACC+FCW trucks .... 75
Table 28: ACC+FCW trucks - results from impact assessment of safety-related hypothesis per road type. .......................................................................................................................75

Table 29: The estimated safety impact of ACC+FCW for trucks based on EU-27 accident data...............................................................................................................................75

Table 30: Overview of estimated safety impacts of ACC+FCW based on EU-27 accident data ......................................................................................................................................75

Table 31: Summary of the impact of ACC+FCW ................................................................78

Table 32: Summary of results ..............................................................................................88

Table 33: Summary of results ..............................................................................................89

Table 34: Summary of results ..............................................................................................92

Table 35: Summary of results ..............................................................................................94

Table 36: Summary of results ..............................................................................................95

Table 37: Summary of results ..............................................................................................97

Table 38: Summary of results ..............................................................................................98

Table 39: Summary of results .............................................................................................100

Table 40: Analysis data on frequency of drowsy driving (passenger cars, ACC+FCW). .....101

Table 41: Significant results: accelerator pedal usage (passenger cars). .........................104

Table 42: Odds Ratios for focus on forward roadway in crash relevant events (passenger cars, ACC+FCW). ..............................................................................................................107

Table 43: Odds Ratios for focus and level of engagement on secondary tasks (passenger cars, ACC+FCW). ..............................................................................................................109

Table 44: Odds Ratios .......................................................................................................110

Table 45: Significant Results: lateral driving performance (passenger cars). ....................113

Table 46: Results from testing whether LDW+IW usage increased during night driving in the treatment period. ................................................................................................................116

Table 47: Significant results: use of turn indicator in lane change situations (passenger cars). ...........................................................................................................................................118

Table 48: Odds Ratios for focus and level of engagement on secondary tasks (passenger cars, LDW+IW). ..................................................................................................................120

Table 49: Odds Ratios for focus and level of engagement on secondary tasks just prior to crash relevant events (passenger cars, ACC+FCW or LDW). ......................................122

Table 50: Result from annotation of events where LDW or IW issued warnings. ...............123

Table 51: Odds Ratios for focus on forward roadway in crash relevant events (passenger cars, LDW+IW). ..................................................................................................................125

Table 52: Analysis data on frequency of drowsy driving (passenger cars, LDW+IW). ........127

Table 53: Results for average speed differences. ...............................................................129

Table 54: Estimated odds ratios and significance for over-speeding events. .................131

Table 55: Estimated odds ratios and significance for strong jerk events occurrence. .......133

Table 56: Estimated odds ratios and significance for critical time gap events occurrence. 135

Table 57: Estimated odds ratios and significance for hard braking events occurrence. ....137

Table 58: Estimated differences between number of incident per 100km. ......................140
Table 59: Results for average speed differences ............................................................... 142
Table 60: Estimated odds ratios and significance for over-speeding events .................. 144
Table 61: Estimated odds ratios and significance for strong jerk events ....................... 146
Table 62: Estimated odds ratios and significance for critical time gap events .................. 148
Table 63: Estimated odds ratios and significance for hard braking events ..................... 150
Table 64: Results for average speed differences between baseline and experiment ......... 153
Table 65: Results of Friedman ANOVAS for incident frequency ................................. 156
Table 66: Means and standard deviation for incident frequency at intersections .......... 156
Table 67: Results of Friedman ANOVAS for proportion of time with close following distance ................................................................. 159
Table 68: Results of Friedman ANOVAS for lane-keeping errors ................................. 161
Table 69: Results of Friedman ANOVAS for number of hard braking events per hour .... 162
Table 70: Results of Friedman ANOVAS for number of hard accelerations .................. 164
Table 71: Analysis data on turn indicator usage (BLIS) .................................................. 166
Table 72: Summary of results: risk of critical THW (trucks) ............................................ 169
Table 73: Summary of results: average speed (trucks) ................................................... 171
Table 74: Summary of results: number of incidents based on vehicle kinematics per 100km (trucks) ................................................................. 173
Table 75: Summary of results: number of incidents based on video annotation per 100km (trucks) ................................................................. 174
Table 76: Summary of results: number of high decelerations per 100 driven km (trucks) .. 176
Table 77: Summary of results: relative risk of strong braking reactions (trucks) ............... 177
Table 78: Summary of results: average THW (trucks) ................................................... 179
Table 79: Summary of results: focus on forward roadway in crash relevant events (trucks, ACC+FCW) ................................................................. 180
Table 80: Summary of results: focus and level of engagement on secondary tasks (trucks, ACC+FCW) ................................................................. 183
Table 81: Summary of results: accelerator pedal usage (trucks) ..................................... 185
Table 82: Significant results: lateral driving performance (trucks) ............................... 189
Table 83: Significant results: use of turn indicator in lane change situations (trucks) ....... 192
Table 84: Odds Ratio for focus on forward roadway in crash relevant events (trucks, LDW). ......................................................................................... 194
Table 85: Odds Ratio for focus and level of engagement on secondary tasks just prior to crash relevant events (trucks, ACC+FCW or LDW) .................. 196
Table 86: Odds Ratio for focus on forward roadway in crash relevant events (trucks, LDW). ......................................................................................... 197
Table 87: Odds Ratio for number of lateral crash relevant events (trucks, LDW) .......... 198
Executive Summary

Improvement of road safety is one of the main challenges for European transportation. A promising route towards reducing road fatalities is through a wider deployment of new in-vehicle technologies that help drivers avoid crashes or to mitigate crash severity. Assessing how well these technologies perform in terms of achieving their intended goals in the real-world is of key importance for making correct business and political decisions regarding their deployment. Such knowledge has so far largely been lacking; hence euroFOT was initiated with the aim of filling this gap by investigating the impact of a number of different functions have on regular drivers in real traffic.

The present deliverable puts together the main results of the safety impact assessment conducted in euroFOT. By testing a multitude of hypotheses on the collected vehicle data and drawing on information from different European crash databases, in deliverable 6.4 we present an analysis that aimed to:

1. Investigate if the evaluated functions improve overall traffic safety;
2. Investigate if the evaluated functions affect other aspects of driver behaviour, including possible negative side effects;
3. Identify the size of the target crash population for each evaluated function, i.e. the set of real-world crashes the function may be able to address in some way;
4. Given that a function affects safety within the experimental vehicle fleet, make a prediction on how the target crash population would change on an EU-27 level if that function was widely deployed;
5. Provide a set of lessons learned hints that future FOT’s can rely upon.

Overall, the safety impact analysis pointed to a positive effect on a number of potentially safety-related measures when the evaluated functions were made available to the driver. Main findings include the following:

- In both cars and trucks, when drivers were following a lead vehicle while using ACC+FCW, time-headway increased significantly, and the relative frequency of harsh braking events and incidents decreased. In terms of changes in driver behaviour, car drivers using ACC+FCW were three times more likely to engage in visual secondary tasks during normal driving (e.g., reading maps, looking at passengers or objects in the car), but this difference was not found during incidents. These results imply that drivers seem to abort secondary tasks and focus on the road ahead when the traffic situation requires it. In addition, ACC+FCW presence does not seem to affect the amount of drowsy driving. For trucks, no particular side effects on driver behaviour were observed.
Table 1: Summary of the impact of ACC+FCW based on the assumption that the selected safety-related measures are good indicators of how the accident population would change if all vehicles were equipped with ACC+FCW

<table>
<thead>
<tr>
<th>Vehicle type</th>
<th>Road type</th>
<th>Usage (portion of the total driving in treatment)</th>
<th>Changes between baseline and treatment in safety related measures in the FOT data. Positive numbers indicate an estimated decrease in risk when ACC+FCW is in use.</th>
<th>Potential reduction in the target crash population (rear end crashes)</th>
<th>Potential reduction in the injury accident population per road type in EU-27</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger Cars</td>
<td>Motorway</td>
<td>51%</td>
<td>32 - 82%</td>
<td>16 - 42%</td>
<td>2.2 - 5.8%</td>
</tr>
<tr>
<td>Passenger Cars</td>
<td>Rural</td>
<td>31%</td>
<td>32 - 45%</td>
<td>10 - 14%</td>
<td>0.47 - 0.65%</td>
</tr>
<tr>
<td>Passenger Cars</td>
<td>Urban</td>
<td>19%</td>
<td>32%</td>
<td>6%</td>
<td>0.14%</td>
</tr>
<tr>
<td>Trucks</td>
<td>Motorway</td>
<td>42%</td>
<td>14 - 36%</td>
<td>6 - 15%</td>
<td>0.2 - 0.6%</td>
</tr>
</tbody>
</table>

In terms of projecting what the safety indicators changes would mean if ACC+FCW were widely deployed, it was concluded that ACC+FCW in passenger cars might have a positive effect on the overall crash population. In trucks, this conclusion could only be made for motorways. Results are summarized in Table 1 and are based on the assumption that the selected safety-related measures are good indicators for how the accident scenario would change if all vehicles were equipped with the bundle. Further estimations based on the addressable rear-end target crash population were also made, e.g., regarding involved injured individuals.

- While driving with LDW (+IW for cars) drivers showed a slightly improved lateral control. A small increase in turn indicator usage was verified, and there was also a trend, though not statistically significant, toward less involvement in lateral incidents. In terms of effects on driver behaviour, car drivers were more likely to engage in secondary tasks—more specifically, using nomadic devices such as mobile phones—while using LDW(+IW) during normal driving. Nevertheless, during incidents, no such difference was found. This finding mirrors results that were also found for ACC+FCW, and seems to indicate that drivers are capable of adjusting secondary task engagement to traffic demands. For trucks, no particular side effects on driver behaviour were observed. While these results overall were positive in terms of how LDW(+IW) could potentially impact safety and driver behaviour, it was also concluded that they were not significant enough and therefore could not be used as a basis for predicting how the EU-27 crash population might change if LDW(+IW) were widely deployed. Further empirical analysis is needed before the potential benefit of LDW(+IW) can be assessed for EU-27.

- For the Speed Regulation System (SL+CC), it has been shown that when SL is active the likelihood of observing an over-speeding or harsh braking event is reduced, but very small or insignificant effects are found for other events (strong jerk or critical time gap). The CC effect on over-speeding is opposite showing a strong increase,
while strong jerk, critical time gap, and hard braking occurrences are reduced. These findings highlight the relationships between system usage and driving conditions, showing that level of traffic is likely to be an important parameter. SRS systems tend to be designed for comfort purposes, and not necessarily for safety issues, although interactions can occur depending on driver’s usage. euroFOT data helped show that no critical or unexpected safety effect occurs when using the system, despite the increase in speed. SRS impact therefore depends largely on the way drivers use it. Given these results and the limitations of the investigated models, our conclusion is that a trustworthy up scaling of SL/CC is not feasible; there are too many uncertainties for results of such an up scaling to be viewed as reliable. Different approaches for understanding the impact of SL/CC on accidents need to be further investigated in future work.

- For the navigation system, it was observed that on urban roads driving is potentially safer if the system is activated. The positive effect on safe driving is reflected in positive changes in lane keeping behaviour, distance to the lead vehicle and hard braking events. Nevertheless, since safety benefits of navigation systems are not reported in the literature and also because no experiment is known that investigates possible mechanisms by which a navigation system might support safe driving, it is difficult to judge whether and under which assumptions the measured effects can be generalized. Because the safety mechanism for the navigation systems is not known, any potential safety benefit caused by navigation systems need further investigation. As a consequence, up-scaling of the measured effects to EU27 is not applicable.

- While driving with BLIS engaged, most hypotheses tested showed no change on safety or driver behaviour related indicators. The only exception was the use of turn indicators, which slightly decreased when the system was available and drivers were not simultaneously using LDW+IW. It was concluded that these results were not sufficiently significant to be used as a basis for predicting how the EU-27 crash population might change if BLIS would have been widely deployed. Further empirical analysis is needed before the potential benefit of BLIS can be assessed for EU-27.

These results have clear implications for both the design, the execution and data analysis in future FOT’s and can, therefore, be used as guidelines for future FOT-based research in this field.
1 Introduction

1.1 Background

Approximately 40 000 fatal crashes occur every year in Europe, and many more involve injured persons. One approach towards a reduction in these numbers is the development of active in-vehicle functions designed to assist the driver in the driving task and help avoid or mitigate the effects of accidents. These functions are now being deployed on the market, and while they have been extensively tested in laboratories, on test tracks and on real roads, the study of their effect on driver behaviour and safety in the complexities of real life driving has so far been limited. The euroFOT project was initiated in an attempt to address this issue.

euroFOT was the first European large-scale Field Operational Test (FOT). An FOT is an evaluation methodology that aims to provide insight into the behaviour of in-vehicle functions in the real-world, and specifically to compare if driving behaviour is altered when one or more functions are made available to the drivers. euroFOT evaluated a number of traffic effects of Advanced Driver Assistance Systems (ADAS) that are already available in the market or are mature enough to be tested as commercial functions. Over 900 vehicles including cars and trucks from a range of manufacturers took part in the study which started in 2008.

While being the first large scale endeavor of this type in Europe, euroFOT is not the first FOT to be conducted. In the U.S., many systems have been extensively tested on a fleet of vehicles by ordinary drivers under naturalistic conditions, i.e. in their own cars and with monitoring equipment mounted as unobtrusively as possible, as part of the IVI (Intelligent Vehicle Initiative) research program. One of the earliest was the Automotive Collision Avoidance System Field Operational Test (ACAS-FOT) by General Motors and the U.S. National Highway Transportation Administration (NHTSA) (1999). This FOT followed 11 ACAS-equipped passenger cars during 12 months of naturalistic driving by ordinary drivers on public roads in the U.S. (Ervin et al., 2005a). More recent examples in the U.S. include the Road Departure Crash Warning System Field Operational Test (RDCW FOT), which gained insight into the suitability of road departure crash warning systems for widespread deployment within the U.S. passenger vehicle fleet (LeBlanc et al., 2007; Sayer et al., 2007) and the Integrated Vehicle-Based Safety Systems (IVBSS), which was a two-phase, multi-year cooperative research effort involving a fleet of 16 passenger cars and 10 heavy trucks with the goal of evaluating the safety benefits and driver acceptance of integrated crash warning systems on prototype level (Sayer et al., 2011). In Europe, previous initiatives include the Sweden-Michigan Field Operational Test (SeMiFOT), which from 2008 to 2010 collected data from cars and trucks in Sweden (SeMiFOT, 2009).

These previous experiences have shown that FOTs are an excellent way to raise awareness, collect large amounts of data from driving in the real world rather than under laboratory conditions, and support the take-up of Intelligent Car Technology solutions. FOTs have also proven to be a powerful tool for gaining insight into the way new functions match user needs and expectations when operated in the ordinary traffic environment under extended periods of time. The latter is of particular importance when it comes to studying everyday usage and behavioural impacts of new technologies.

In euroFOT, eight functions were investigated at five test sites across Europe: Sweden, Germany (two test sites), Italy, and France. They are:

- **Longitudinal functions**: Adaptive Cruise Control (ACC) and Forward Collision Warning (FCW) together in one bundle (counted as one function) and Speed Regulation System (SRS): Speed Limiter (SL) and Cruise Control (CC).

- **Lateral functions**: Lane Departure Warning (LDW), Impairment Warning (IW), and Blind Spot Information System (BLIS). LDW and IW were analysed together as a bundle in cars.
• **Other functions:** Curve Speed Warning (CSW), Fuel Efficiency Advisory (FEA), and Safe Human-Machine Interaction (Navigation System).

This deliverable (D6.4) offers the final results of the impact of studied functions on traffic safety. A description of the safety impact methodology can be found in the euroFOT Deliverable 6.2.

In euroFOT, D6.4 is part of work package (WP) 6400 (Impact Assessment), which belongs to sub-project (SP) 6 (Evaluation, Impact Assessment, Socio-economic CBA). SP6 is the analysis sub-project of euroFOT, in which user-related aspects, traffic efficiency, environment, and safety are investigated.

### 1.2 Impact Assessment

Impact assessment is comprised of a set of logical steps which help to quantify the potential consequences that the studied function may have. Ultimately, in D6.4, the extent to which selected functions being evaluated in euroFOT can be expected to alter the current crash populations on an EU level in terms of accidents, injuries, and fatalities were assessed. The general safety impact process is illustrated in Figure 1. It has three main steps:

1. **Defining the target crash population (define problem size).** This step involves finding out from national crash databases in the countries where the functions are being evaluated, how many function-relevant crashes (i.e. crashes that the function could potentially help to address) occur on an annual basis. This topic is covered in chapter 6.

2. **Identifying changes in safety-related measures between baseline and treatment (FOT data analysis).** This step involves testing a number of pre-defined hypotheses on how various safety-related measures might change between baseline and treatment in the collected data for the functions evaluated. This topic is the core element of this deliverable and where most of the time was spent. It is covered in chapter 5.

3. **Interpreting what any significant change in these metrics means, in terms of a generalized safety impact estimate on the EU-27 level (interpreting results).** In this step it is estimated, based on the identified changes in step 2, how the number of accidents, injuries and fatalities could be expected to change in the national crash population if the evaluated functions were to be nationally deployed (chapter 7). Where possible the results are then extrapolated to the rest of the EU, i.e. trying to project what would happen in the full EU-27 driving population if the functions were deployed EU-wide (chapter 8).
While the three general steps above can be said to be common for all impact assessments, the detailed implementation can differ substantially between projects. For example, real crashes occur very rarely during FOTs. This is because even though a lot of mileage is accumulated during FOTs, the actual crash risk for an ordinary driver is very low. This means that actual crashes cannot be used to assess the impact of a particular technology, at least not on a level where statistically significant differences can be shown. Instead some surrogate safety-related measures have to be devised, i.e. some type of driving event for which one assumes that if its frequency of occurrence changes in the treatment phase (i.e. when the evaluated technology is present in the vehicle), then general crash involvement will also change if the technology was widely deployed.

The way this type of safety-related measure is implemented differs between various impact assessment approaches. For example, both RDCW (LeBlanc et al., 2006), and ACAT (Gordon et al., 2010) studied the impact of Lane Departure Warning on safety and used driver’s actual lane departures as a conflict measure. However, while RDCW focused on lane departure frequency, ACAT rather focused on lane departure duration and lateral extent.

Another example would be the approach used in ACAS-FOT (Ervin et al., 2005b). Rather than using the common approach of looking for driver responses such as hard braking or emergency steering maneuvers in the collected data to identify conflicts, they based their conflict definition on a test track study where drivers were asked to brake as late as they deemed possible when approaching a vehicle mockup ahead. Hence their conflict definition became independent of actual driver response in the FOT data.

Different works aiming at quantifying the potential benefit of safety function have been conducted. Table 2 shows the reported benefit of various functions according to different

![Figure 1: Overview of the safety impact process and the data sources used. Numbers on the left side indicate the chapter in which each topic is addressed. The output is dealt with in deliverable 6.7.](image-url)
sources in the literature. Results vary significantly depending on the evaluation methodology and experimental setup (a more extensive review can be found in Bayly M. et al., 2007).

Table 2: Impact of different functions in the literature.

<table>
<thead>
<tr>
<th>Source</th>
<th>Vehicle type</th>
<th>Reduction in crashes (unless otherwise specified, reduction applies to target crash population)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FCW</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NHTSA, 2001, cited in Bayly M. et al., 2007</td>
<td>Passenger cars</td>
<td>48%</td>
</tr>
<tr>
<td>Regan, et al., 2002, cited in Bayly M. et al., 2007</td>
<td>Passenger cars</td>
<td>7%</td>
</tr>
<tr>
<td>Fitch G. et al., 2008</td>
<td>Heavy vehicles</td>
<td>21%</td>
</tr>
<tr>
<td><strong>ACC</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elvik, et al., 1997, cited in OECD, 2003</td>
<td>Motorized vehicles</td>
<td>5.9% (reduction in total number of all crash types)</td>
</tr>
<tr>
<td>Abele, et al., 2005, cited in Bayly M. et al., 2007</td>
<td>Passenger cars</td>
<td>25%</td>
</tr>
<tr>
<td><strong>ACC+FCW</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Najm W. Ference, 2006</td>
<td>Passenger cars</td>
<td>3% – 26%</td>
</tr>
<tr>
<td><strong>LDW</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wilson et al., 2007</td>
<td>Passenger cars</td>
<td>10% – 60%</td>
</tr>
<tr>
<td>Gordon et al., 2010</td>
<td>Passenger cars</td>
<td>13% – 31.5%</td>
</tr>
<tr>
<td>Korse, 2003, cited in Bayly M. et al., 2007</td>
<td>Heavy vehicles</td>
<td>10% (reduction in the total number of heavy vehicle crashes)</td>
</tr>
<tr>
<td><strong>ACC+FCW+ESP</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hautzinger et. al., 2012</td>
<td>Heavy vehicles</td>
<td>34% (reduction of general accident risk measured in accidents per 1 million kilometres)</td>
</tr>
</tbody>
</table>

More examples could be given, but the ones above serve to illustrate the point that there is no general consensus in the literature on how to best approach impact assessment on the detailed level. In many aspects euroFOT has adopted a unique experimental setup, and has therefore defined its own safety impact methodology to handle these particular aspects.

In euroFOT, of the three main steps earlier described, steps (1) and (2) are based on processing of empirical data, i.e. they rely on vehicle data collected during the study (e.g., CAN signals, GPS data, video recordings) and on data from national crash databases. Step (3) on the other hand is not based on empirical data per se; rather it is based on a set of assumptions on how the findings from steps (1) and (2) can be extrapolated in order to make a prediction of how the studied functions may impact traffic safety in general. Since assumptions always come with limitations, it is important that these are taken into account when reading the results and trying to put them in perspective. We have carefully analyzed
each of these limitations and put together a list of lessons learned on how future FOT’s can benefit further from the work presented here. This list is available in chapter 10.

Another important point to make here is that for certain functions, it was not possible to carry out the third step, i.e. to make a prediction on whether the crash population in EU-27 would change if the function were widely deployed. There are several reasons for this, which are further explained in chapters 6 and 7. Nevertheless, an overall benefit of all functions is offered in chapter 5 with the main findings divided into cars and trucks. Before reading chapter 5, the reader is encouraged to go through chapter 3, in which the methodology described in deliverable 6.2 is shortly reviewed, and chapter 4, where the expected benefits of studied functions are presented. The output of the safety impact analysis serves as one of the inputs to the Cost Benefit Analysis (CBA), discussed in deliverable 6.7.

Furthermore, it is crucial to differentiate between goal (general focus on input or output of assessment) and direction of scope (ex-ante vs. ex-post) of the impact assessment:

- Theoretic studies like eIMPACT are ex-ante assessments of future assistance systems and intended to provide a socio-economic overview on what could change because of these functions. The safety impact methodology distinguished between risk, exposure and consequence, intended to capture a wide range of potential mechanisms, but without actually empirically proving them. The methodology development rather looked at comprehensively defining and quantifying all possible mechanisms by which systems can influence risk, exposure and consequence both directly and indirectly. Hence as a necessary output, this framework could be used to estimate all potential reductions in fatalities and injuries for the considered future systems.

- In field tests, significant changes in crash-related indicators are the key outcome in terms of safety. Inputs for the assessment necessarily are real-world effects of real systems. The indicators allow observing effects how systems could on a larger scale help lowering accident risk in specific constellations. To be methodologically consistent, making a link and up-scale from FOT to accident data level already would be outside the scope of the experimental setup of a field test, if no reduction of real accidents is observed. But being this strict, the results of euroFOT could not be used to estimate any expectable impacts on accidents or injuries at all - since the results do not directly allow predicting any changes in terms of road safety improvement.

In order to be in line with FESTA methodology, only significant and unequivocal changes in events were linked to addressable accidents that were - by using definitions according to system limitations - filtered to a level to limit the error. In future analysis, further research should aim at linking both scope and requirements of the two approaches, e.g., a detailed analysis of FOT data for effectiveness and case-by-case analysis from in-depth accident data could be used to review the full set of safety mechanisms for more functions that were intuitively assumed in eIMPACT.

1.3 Relationship with other sub-projects and deliverables in euroFOT

Interaction with other SPs was essential for the work carried out in WP6400. The requirements for the assessments had to be considered by the other SPs from the beginning. In this section, the most important of these connections and interactions are described.

- SP2 (In-Vehicle Systems for Driving Support) provided the requirements and specifications of the selected functions in Deliverable 2.1 (Specifications and Requirements for Testing In-vehicle Systems for Driving Support). Relevant activities in SP2 include, for example, formulation of hypotheses and selection of preferred analyses.
• SP3 (Data Management) provided the data specification, data structure and format (database), data storage, and analysis tools. The requirements of SP6 with regard to data to be measured were considered in SP3.

• SP4 (Methodology and Experimental Procedures) defined the evaluation criteria (experimental procedures) and performance indicators. SP4 and SP6 have very strong relations. Relevant documents are Deliverable 4.1 (Report on specification of performance indicators) and Deliverable 4.2 (Report on specification of experimental procedures).

• SP5 (Vehicle and Test Management Centre) collected the FOT data used in the impact assessment. This SP also took care of quality management. A document that is important for SP6 is Deliverable 5.3 (Final delivery of data and answers to questionnaires).

• A detailed description of the safety impact methodology can be found in the euroFOT Deliverable 6.2 (Analysis methods for user related aspects and impact assessment on traffic safety, traffic efficiency and environment). The reader is encouraged to refer to this deliverable whenever necessary.

• A review of the test sites including test duration (baseline, treatment, kms driven and months driven in each), number and critical information about drivers (company employees, age, driving experience, etc) can be found in Deliverable 6.3 (Final results: User acceptance and user-related aspects).
2 A short review of the safety impact methodology

In this chapter we provide a short summary of the safety impact methodology described in details in deliverable 6.2. As mentioned earlier in the introduction, the safety impact analysis can be divided into three major steps, which are better explained below together with a discussion on methodological concerns.

Defining the target crash population

The first part of the safety benefit analysis is fairly straightforward. It involves defining the target crash population, i.e. the set of crashes (including the associated set of injuries and fatalities) which a particular function could potentially help to address. For example, for Forward Collision Warning (FCW) this is the set of rear end crashes which occur within the function’s operational scope (certain ego vehicle speeds and approaching speeds to lead vehicle). For Lane Departure Warning (LDW), this is the set of crashes which start with an unintentional lane departure, and again, which are within the functions operational scope (visible lane markers, above certain vehicle speed, etc).

Once the target crashes have been identified, data describing the crash circumstances was cross tabulated to identify the most typical conditions under which these crashes occur. The rationale for this step is to provide a set of filters that can be used to exclude some of the empirical data from the analysis. In principle, any ADAS driven change which occurs outside the envelope of crash typical circumstances will not affect the safety impact, since by definition no relevant crashes occur outside those conditions. Leaving those data portions out of the analysis thus strengthens the link between the empirical data and the target crash population.

Identifying changes in safety-related measures between baseline and treatment

The second part of the methodology is quantifying any safety relevant difference that the presence of an ADAS generates in the empirical data, i.e. quantifying any changes in crash risk between baseline (no ADAS) and treatment (ADAS present). For this purpose, a partially new methodology was developed in euroFOT.

In terms of how the methodology is set up, it is first important to recognize that it was known before the project started that the number of actual crashes that would occur would be very limited. Even when hundreds of drivers are being observed during a full year or more, the statistical likelihood of a crash occurring is so low that it uncertain whether there would be any police reported crash in the data.

This meant that the most direct measure of change in crash risk, i.e. the number of crashes which occur with and without the ADAS, is not available, at least not in sufficient numbers to reliably quantify a difference between baseline and treatment. Hence other indicators of change in crash risk had to be defined, such as the frequency of safety critical events or changes in driver behaviors that are known to be crash causation related. In other words, to determine whether a particular ADAS is successful in preventing a certain crash type, one must first have an understanding of why that crash type occurs. When that understanding is in place, a measure of change that captures the function’s impact on that particular crash causation mechanism(s) can be defined.

For example, many rear end crashes are thought to occur due to unexpected lead vehicle braking while the driver is visually distracted from the forward roadway (Dingus, T. A. et al., 2006). In relation to this crash causation mechanism, FCW can be understood as a tool for interrupting the driver’s state of visual distraction and redirecting his/her attention to the forward roadway and the braking of the lead vehicle. If FCW is successful in this regard, one would expect e.g. a decrease in the number of panic braking events when drivers are using
FCW. The frequency of panic braking events can therefore be used as an indicator of change in crash risk due to the presence of FCW.

To facilitate the process of identifying changes between baseline and treatment in the collected euroFOT data, a number of hypotheses on how various safety-related measures may be impacted by ADAS presence were formulated (D6.2, Annex 2A). Testing whether these hypotheses hold or not essentially forms the core of this second step of the methodology. Depending on the function analysed and the hypothesis to be answered (i.e. how the function’s influence on some crash causation mechanisms is conceived), three principal ways of doing the analysis were applied accordingly.

**A. Events Based Analysis (EBA)**

The first analysis method is Event Based Analysis (EBA). Here the aim is to find out whether the frequency of safety critical driving situations changes when a safety function is made available to the driver. The basic principle of EBA in a FOT context is to identify relatively short time segments (events), thought to be predictive of crash involvement, and then compare the frequency of these in baseline (meaning no ADAS is present to support the driver) and treatment (the ADAS is available and in use, i.e. switched on and working properly). For a more detailed description, see Section 4.1.1. ACC+FCW – Data Selection. Examples of events are actual crashes, as well as situations where the driver performs a violent evasive manoeuvre, i.e. where the distance in time and/or space from an actual crash is very small (near crashes/incidents). These events can be identified retrospectively in the driving data, together with interaction/confounding factors such as road type, speed limit, traffic conditions, other functions etc.

**B. Aggregation Based Analysis (ABA)**

The second is Aggregation Based Analysis (ABA). Here the aim is to identify any significant changes between baseline and treatment in aggregated continuous data, such as mean speed or average time headway. In other words, it captures the change between baseline and treatment in terms of how driving performance changes over longer periods of time. This type of analysis is primarily relevant for answering hypotheses on e.g. whether the average following distance or travel speed decreases as a function of ADAS presence. In ABA, a method called chunking is often used. Chunking means sampling the data in ‘chunks’ of e.g. one minute. See euroFOT deliverable 6.2 on the methodology for more details.

**C. Risk Matrix Approach (RMA)**

The risk matrix approach, as applied here, uses computer simulation of longitudinal vehicle conflict risk to estimate any change in risk when a vehicle is fitted with ACC+FCW. The change is called the Risk Modification Factor (RMF), and it is calculated by dividing the risk in baseline with the risk in treatment. A RMF below one suggests that driving is safer in the treatment period. Monte Carlo simulations are performed to quantify conflict risk in a wide spectrum of car following situations, and risk in the FOT data is then assessed by mapping the empirical data on car-following behaviour to the simulated risks.

**Choice of method**

Note that EBA, ABA, and RMA are complementary forms of analysis which explore the impact of an ADAS from different angles, based on how the ADAS safety impact is conceptualized in terms of influence on crash causation (i.e. which hypothesis are selected to being tested for the function). For ACC+FCW for example, a potential increase in average time headway is best investigated with an ABA analysis, while a potential decrease in the number of lead vehicle conflicts is best investigated with an EBA or RMA type of analysis.

**Interpreting what any identified change between baseline and treatment means in terms of a generalised safety impact on the EU-27 level**

The third part of the methodology is taking the quantified differences between baseline and treatment and calculating what it can mean in terms of reducing the full crash population on an EU-27 wide level. This is done in three steps. The first is to decide which of the identified differences are to be used for the actual prediction. The second is to calculate the reduction
in crashes based on accident data, filtered is as much detail as possible, on the national level. The third is to extrapolate those results to the EU-27 wide crash population level. Below, these parts are addressed in turn. However, note that where the link between changes between baseline and treatment and crash causation is weak, any predicted change in the target crash population if the evaluated ADAS were to be widely introduced, should only be seen as a general indication of a positive influence of ADAS on the wider target population. This is true at both the national and EU levels.

**Step 3A: Statistically testing size and significance of identified effects**

First, there is the issue of size and significance of an identified difference between baseline and treatment, or between some other comparison conditions (like at various times during treatment). To test this, many different methods are available, depending on the data analysed and the hypothesis to be addressed. For ABA data analysis, which typically becomes a comparison of means in baseline and treatment, or changes in means over time as drivers use a particular function more and more, various types of variance and regression analysis can be applied, such as ANOVA and linear regression models.

When it comes to analysing EBA data, i.e. to compare event frequencies in baseline and treatment, also many different methods are available. The simplest form of comparison is to make a contingency table by counting the frequency of events in baseline and treatment conditions (based on some form of exposure normalisation, such as the number of events per driving hour) for each driver to understand, whether ADAS presence causes a change in event frequency. More sophisticated statistical models that handle driver-specific correlations (i.e. some drivers will experience more events than others) and confounding factors can also be used, such as the “Generalized Estimated Equations” (GEE) model, originally developed to model longitudinal data, assuming that observations are marginally correlated or the “Generalized Linear Mixed Models” (GLMM).

**Step 3B: Impact on the national level**

If a significant difference between baseline and treatment has been established for an ADAS in terms of a safety-related measure, the next step is to make an impact estimation based on that difference. This means that one has to interpret what the identified difference actually means in terms of how the target crash population can be expected to change if the function is widely deployed.

This impact estimate should first be carried out for the national level, i.e. for the country in which the function is being evaluated. Next, the national impact should be projected onto a wider EU-27 scale (Step 3C below). This two-step approach was chosen because when selecting which part of the FOT data to look for changes in, crash conditions are a very relevant input. For a best fit with the data collected, it makes sense to use crash conditions from the country where each respective system is being evaluated. Once the national analysis is done, the effect of a comparable relative change in other countries can be assessed.

The national impact estimation can be carried out at various levels of detail. The least detailed approach is to apply the identified change to the whole target crash population. For example, if the frequency of FCW relevant near crashes turns out to be 20% lower in the treatment phase, one might use this to predict a 20% decrease in FCW relevant crashes and injuries if all vehicles were equipped with FCW.

A more detailed version of the same thing would be to first calculate the impact for individual conditions in the target crash population, and then sum up the total impact. For example, if there are 2000 rural and 3000 urban FCW relevant crashes in the target crash population, the analysis might find that while the near crash reduction ratio is 25% for urban environments its only 17% for rural roads. In this case, the total safety impact would be calculated for urban and rural roads individually before summing up, i.e. the potential reduction in crashes would be $0.17 \times 2000 + 0.25 \times 3000 / 5000 = 21.8\%$.

While the more detailed approach naturally is preferable, it also requires larger significant effects to be meaningful, since differences quickly shrink when one the list of dividing
conditions grows longer. Thus one has to balance the desired level of detail in the impact assessment with minimum requirements on how many events per condition are needed to test for statistically significant differences between baseline and treatment.

**Step 3C: Impact on the EU-27 level**

In this step, one integrates the national impacts as identified above and then project these estimations onto the crash population in the EU-27. To extend a national impact to the EU level, one thus first has to map the crash shares affected by the evaluated functions on the national level to an EU-27 crash population. For example, if the national impact predictions for a function evaluated in Sweden and Germany says that 5% of rear end crashes in Sweden and 7% of rear end crashes in Germany would be addressed if all vehicles were equipped with this feature in these countries, then one has to take a meaningful average of these two impacts (simplest form: 6%), and calculate what a 6% reduction of rear end crashes means in terms of accident and injury reduction for all EU-27 countries.

**Methodological concerns**

In relation to the different ways of estimating a safety impact for the euroFOT functions described above, there are a number of methodological concerns that can be raised. Some of the most important ones are discussed in turn below. Note that these issues are not meant to diminish the quality and effort of the work underlying this deliverable; they are simply a set of key issues that need to be kept in mind when going through the results presented, to avoid drawing too extended conclusions from the findings.

First, the relationship between changes in the evaluated safety-related measures, when comparing baseline and treatment, and accident involvement is not straightforward. This is a problem for all three approaches (ABA, EBA and RMA) described above. Ideally, one would select and compare only events and/or aggregate measures which are known to be predictive of actual crash involvement, i.e. where it is legitimate to infer that a particular change in what is measured corresponds to a particular change in crash frequency. If this relationship is established, an experimentally identified reduction in the treatment phase could then be used to directly predict a reduction in future crash involvement.

Unfortunately, such relationships are yet not fully established, at least not for FOT type data. For example, in terms of events, while hard braking may seem a plausible candidate for event selection, in the VTTI 100 car study (Dingus, T. A. et al., 2006) they were not able to reliably identify near-crash events in lead vehicle following situations based on hard braking alone, i.e. such braking occurred also in many driving situations which they did not think were indicative of crash risk. Similarly but in terms of aggregate measures, while a reduction in mean speed could be indicative of a reduction in crash involvement, there is no empirical base available for estimating the importance of mean vehicle speed in FOT data in relation to crash involvement. It follows that insight into crash causation mechanisms is key to the selection and interpretation of relevant measures of change between baseline and treatment, and where the link to crash causation is weak, any predicted change in the target crash population if the evaluated ADAS were to be widely introduced is to be used with a great deal of caution.

Second, in euroFOT, a number of hypotheses on change in safety-related measures are being tested. In an ideal world, it could be hoped that all tested indicators for a particular function would point in the same direction, whether it is toward a general increase or decrease in perceived safety in treatment. However, most likely there will be contrasting findings, as well as some statistically significant and other not significant results. This means that an important part of the impact assessment is to find a way to tell the overall story of each function’s potential impact, given how its particular set of indicators come out from the empirical data analysis. Presenting the results of the indicators only will not suffice for a full impact analysis; some form of an integrated narrative has to be constructed as part of the impact assessment.
In light of these methodological concerns, it is important to avoid misuse of this study. For example, it would be incorrect and scientifically unsupported to use this study to assert that any individual accident would have been affected by the presence of any of the technologies on any particular vehicle. Similarly, this study does not support any claim that a vehicle not equipped with any of these technologies is unsafe or defective in any way.
3 A short review of studied functions

3.1 ACC+FCW

A list of partners involved in collecting ACC+FCW data is as follows:

<table>
<thead>
<tr>
<th>Ford</th>
<th>MAN</th>
<th>VOLVO</th>
<th>VCC</th>
<th>VW</th>
<th>CRF</th>
<th>IFSTTAR</th>
<th>BMW</th>
<th>DAG</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Function description

The ACC function supports the driver at the operational level in selecting (and then automatically maintaining) a selected speed and distance to the vehicle in front depending on his/her preferences. Pre-defined settings of the ACC time-headway depend on the OEM, but they usually range from 1 to 3.5 seconds. The system is disengaged when the driver acts on the brake or when the driver pushes the related disengage button (in case of manual transmission, changing gear will also disengage the function). The function is not active below a certain speed or when the vehicle is started. The function needs to be resumed in order to work after the vehicle experienced a speed below a certain threshold (see deliverable D2.1 for detailed specifications). When activating the function for the first time after the engine was shut down settings for following distance and speed are reset.

The main expected benefits from the ACC function were to:

- Reduce exposure time to under-running critical headways;
- Increase driving comfort by automatic adjustment of distance and speed;
- Lower driver stress by decreasing drivers' workload especially on long trips;
- Prevent speeding by setting a limit to the speed;
- Reduce time gaps to the leading vehicle.

In euroFOT, ACC was analysed together with the collision warning function as a bundle. A collision warning function provides alerts to assist drivers in avoiding or reducing the severity of crashes involving the equipped vehicle striking the rear of another vehicle. This function is intended to decrease drivers reaction time in case of potential rear-end accidents. This function supports the driver at the operational level and not at the tactical or strategic level, according to definition from Michon (1985).

Over 780,000 km for cars and 570,000 km for trucks were used in the hypothesis testing for ACC+FCW. More details can be found within each hypothesis template in chapter 5.

Main function boundary conditions common to all OEMs

Demographical requirements/ driver requirements

No specific restrictions. However, the driver needs some time to learn how to use all buttons and how the system works. So, a naive subject using ACC+FCW will experience some learning and adaptation to the system in the first few drives.

Geographical requirements/ road context

Depending on the viewing angle of the used sensors, e.g. radar, the function can lose track of the vehicle ahead in (narrow) curves. As a consequence this function is more efficient on highways than on curvy roads. Further, the system is designed for use on well-built highways and expressways but not in city traffic.
Geographical requirements/ environmental restrictions

This function should not be sensitive to temperature, humidity, and air pressure (at least in normal driving situation). However, depending on the perception sensors of the system implementing this function, heavy rain, snow, and fog may limit the function performance.

Situational requirements/ traffic context

Since this function needs to be reactivated every time the vehicle goes below a set speed threshold it may not be as comfortable when the vehicle experience many consecutive stops at traffic lights. Finally, since this function does not work below a set speed threshold, it cannot be used when traffic is very congested. Systems with additional Stop & Go functionality may be used to a limited extend also in traffic-jam situations, however the ACC systems tested in euroFOT did not have this function.

Other limitations

Depending on the system performance the lower limit of the velocity is between 0 and 30 km/h (FCW between 7 and 30 km/h). The system does not work and is not intended to work while driving in reverse. It is important to note, that the systems under test do not react to stationary objects.

3.2 LDW(+IW for cars)

A list of partners involved in collecting objective LDW data is as follows:

<table>
<thead>
<tr>
<th>Ford</th>
<th>MAN</th>
<th>VOLVO</th>
<th>VCC</th>
<th>VW</th>
<th>CRF</th>
<th>IFSTTAR</th>
<th>BMW</th>
<th>DAG</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Function description

LDW uses lane markings to monitor the vehicle’s position on the lane. LDW continuously assess the vehicle’s relative position on the road and a warning is issued to the driver if the vehicle unintentionally (e.g., not using the turn indicators when crossing the lane marker) deviates from its intended lane. LDW supports the driver at the operational level.

The main expected benefits from LDW were:

- Helping the driver not to drift from the intended lane;
- Reducing the number of lateral collisions;
- Reducing the number of driver impairment accidents caused by drowsiness.

In cars, LDW was analysed together with another function: the Impairment Warning (IW). IW is intended to attract the driver’s attention when he/she starts to drive less consistently, e.g., if he/she becomes distracted or starts to fall asleep. A camera detects the lane markings painted on the carriageway and compares the section of the road with the driver’s steering wheel movements. The driver is alerted if the vehicle does not follow the carriageway in a manner consistent with alert driving. The objective for IW is to detect slowly deteriorating driving ability and it is primarily intended for major roads. The function is not intended for city traffic.

LDW data was also originally planned to be collected for trucks in Germany; however, for various reasons this was not possible. Over 279 000 km for cars and 957 000 km for trucks were used in the hypothesis testing for LDW(+IW). More details can be found within each hypothesis template in chapter 5.
Main function boundary conditions common to all OEMs

**Infrastructure requirements**

Clear consistent and well-maintained, road lane marking are fundamental for LDW(+IW) to work. The system is not designed to function when lane markings are variable such as at road exits, road entries, construction sites and intersections.

**Demographical requirements/ driver requirements**

No specific restrictions. However, the driver needs some time to learn how to engage the systems and how the system works. So, a naive subject using LDW(+IW) will experience some learning and adaptation to the system in the first few drives.

**Geographical requirements/ road context**

LDW(+IW) uses lane boundaries to monitor the vehicle's position on the lane. Depending on the perception sensors of the system implementing LDW(+IW) (in most cases a lane tracker camera and image processing) the following road contexts might cause problems:

- Using a lane tracker camera; lane boundaries are needed on the road in order for the system to operate correctly.
- Issues concerning colour, size and visibility of the lane boundaries must be considered. Restriction regarding road route marking is required.
- Lane width. A maximum and a minimum lane width are required.
- Uneven roads (hills, slopes etc might limit the sensors field of view; FOV). The FOV needs to be specified in regards to the inclination.
- Sharp curves. The FOV needs to be specified in regards to curvature.
- Road surfaces (Bad or varying road basis, e. g. concrete, asphalt and/ or cobbled pavement roads)
- Incidental visible road features (see definitions) might confuse the LDW(+IW) system.

As an example, the Volvo sensor is designed to detect:

- Distance to left lane marking (m)
- Distance to right lane marking (m)
- Level of confidence of measurement (distance quality factor)
- Curvature
- Lane marker type (left/ right)
  - No line detected
  - Continuous
  - Dashed
  - Ragged
  - Reserved
- Error indicator
- Lane position status

**Geographical requirements/ environmental restrictions**
LDW(+IW) should not be sensitive to temperature, humidity, and air pressure (at least in normal driving situation). However, depending on the perception sensors of the system implementing this function the following environmental condition might cause problems:

- Different lighting conditions (fixed or rapid changing lighting conditions, for instance in tunnels or blinding light from the sun)
- Weather conditions (e.g. snow on the road route markings)

**Situational requirements/ traffic context**

LDW(+IW) should not be sensitive to different traffic contexts. However, depending on the perception sensors of the system and the image processing implementing this function obstacles on the road (e.g. vehicle in front) or at the road (e.g. road signs) might confuse the system.

**Other limitations**

The function is active only above a certain OEM-specific speed.

Windshield must be clean for the camera to recognize the lane marking.

When turn indicator is on, the system is automatically in stand-by.

The LDW(+IW) camera needs to be calibrated in order to work properly. This procedure is delicate and is needed at production, any time the camera is moved.

### 3.3 Speed Limiter and Cruise Control (SL+CC)

A list of partners involved in collecting SL+CC data is as follows:

<table>
<thead>
<tr>
<th>Ford</th>
<th>MAN</th>
<th>VOLVO</th>
<th>VCC</th>
<th>VW</th>
<th>CRF</th>
<th>IFSTTAR/CEESAR</th>
<th>BMW</th>
<th>DAG</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Function description**

This Speed Limiter function limits the speed of the car in order to prevent the driver from exceeding a driver selected value. This limit value is pre-set by the driver during the system activation. The minimum value of this speed limit is 30 km/h. This function can be OFF or ON. When it is ON, it can be active or inactive. When it is ON and active, it is only restrictive when the speed of the car reaches the programmed value. When it is restrictive, it can be temporarily overridden by driver action.

The Cruise Control function maintains a constant speed without any manual control by the driver. This speed is programmed by the driver. This function can be OFF or ON. When it is ON, it can be active or inactive. When it is active, it can be overridden at any time. The system can only be activated when the speed is above 30 km/h.

The two functions Speed Limiter and Cruise Control help the driver to manage the speed and cannot be used simultaneously.
The main expected benefits from SL+CC were:

- Increase comfort and pleasure to drive;
- Helping the driver to comply with legal speed limits;
- Helping the driver to maintain a constant speed leading to fuel savings.

This system is not designed to provide any specific safety benefits.

Over 387,000 km were used in the hypothesis testing for SRS. More details on data selection can be found within each hypothesis template in chapter 5, while more details on data description (drivers, number of trips etc.) can be found in deliverable 6.3.

**Main function boundary conditions common to all OEMs**

**Demographical requirements/ driver requirements**

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>n/a</td>
<td></td>
</tr>
</tbody>
</table>

**Geographical requirements/ road context**

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>n/a</td>
<td></td>
</tr>
</tbody>
</table>

**Geographical requirements/ environmental restrictions**

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>n/a</td>
<td></td>
</tr>
</tbody>
</table>

**Other limitations**

The system tested in euroFOT can only be activated when the speed is above 30 km/h and the two last gear box positions (position 4/5 and 5/6) are engaged.

### 3.4 Navigation System

A list of partners involved in collecting Navigation System data is as follows:

<table>
<thead>
<tr>
<th>Partner</th>
<th>参与合作伙伴</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ford</td>
<td>MAN</td>
</tr>
<tr>
<td>VOLVO</td>
<td>VCC</td>
</tr>
<tr>
<td>VW</td>
<td>CRF</td>
</tr>
<tr>
<td>IFSTTAR</td>
<td>BMW</td>
</tr>
<tr>
<td></td>
<td>DAG</td>
</tr>
</tbody>
</table>

**Function description**

Navigation guides the user to his destination according to the objective function, which typically optimises travel time or travel distance. A dynamic navigation system takes also dynamic traffic information into account and reroutes if necessary.

This function uses a positioning system to estimate its position, and certain algorithms to calculate the "best" path to the destination in terms of travel time or distance. The calculation is based on information stored in a digital map, whose attributes (costs in terms of time and length) might be updated dynamically due to actual TMC information.

Results of two recent field experiments in the Netherlands (Vonk et al., 2007) and in Germany (Schießl & Baumann, 2010) have shown that the use of a navigation system to drive in unfamiliar surroundings reduces the number of kilometres and the journey time compared to using conventional navigation methods. In both studies three different experimental conditions were tested: (1) Driving to a destination using a mobile navigation system (2) Driving to a destination using conventional methods (maps, digital route planners on the Internet, etc.) and free choice of the route (3) Driving to a destination using conventional methods, but on the journey the driver had to drive past specific points. The test participants were not familiar with the test area.
In the experiment conducted in the Netherlands the number of stops and the halt times decreased when the drivers used the navigation system, whereas in the German experiment no differences for the halt time and number of stops were observed.

In both studies no differences in the efficient fuel use (litres per 100 km) between the journeys travelled with or without a navigation system were found. Considering that the number of kilometres decreased for the journeys with a navigation system, it could be assumed that the total fuel consumption is reduced by a navigation system.

Concerning workload a reduction was observed when the drivers used the navigation system compared to conventional navigation methods.

Benefits could be assumed not only when the driver uses a navigation system to drive in unfamiliar surroundings, but also when he uses it to drive in a familiar area, in the case there is a traffic jam on his route. In this case, if TMC is available, the navigation system informs the driver about the obstructions on his route and provides information about alternative routes, which may not be familiar to the driver.

In euroFOT, two navigation systems with different levels of integration were compared. All participants tested a built-in system provided by the car manufacturer and a mobile device. Both systems offered the basic routing function as well as the option to provide routing advice that takes the current traffic situation into account and to dynamically adapts the route chosen to the current traffic situation (dynamic routing function). For all tested systems it was only possible to log whether the routing function was active or not. It could not be logged whether the drivers followed the routing advice given by the system. Because of that the compliance with the system cannot be taken into account in the analysis.

It is expected that the familiarity of a trip is a fundamental moderating factor that might influence the effects of a navigation system. All drivers were instructed to rate the familiarity of the oncoming trip at the beginning of each drive by pressing a button. A trip was considered to be unfamiliar if at least a part of the route was not known to the driver.

Over 919 000 km were used in the hypothesis testing for the Navigation System. More details can be found within each hypothesis template in chapter 5.

**Main function boundary conditions common to all OEMs**

**Infrastructure requirements**

For dynamic navigation traffic information shall be available. This is derived from a network of infrastructural sensors or broadcast messages.

**Demographical requirements/ driver requirements**

n/a

**Geographical requirements/ road context**

Although the GPS signal is not available in tunnels, route guidance is still available based on approximations about the travelled distance made on vehicle speed.

**Geographical requirements/ environmental restrictions**

Depending on the transmission technology used by this function bad weather can interfere with this function.

**Situational requirements/ traffic context**

No restrictions

**Other limitations**

Dynamic navigation needs high quality traffic state information; otherwise, the possible rerouting might result in suboptimal routes. Maps used for route calculations should be as up-to-date as possible to avoid mistakes resulting from
outdated attribution. Anytime the position estimation is below an acceptable accuracy (for instance due to long time absence of GPS information).

### 3.5 BLIS

A list of partners involved in collecting BLIS data is as follows:

<table>
<thead>
<tr>
<th></th>
<th>Ford</th>
<th>MAN</th>
<th>VOLVO</th>
<th>VCC</th>
<th>VW</th>
<th>CRF</th>
<th>IFSTTAR</th>
<th>BMW</th>
<th>DAG</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Function description**

A blind spot warning system provides feedback to the driver in case an object has been detected in one of the blind spots of the vehicle.

This function continuously monitors the rear blind spots on both sides of the vehicle. In case an obstacle is detected in the blind spot an information/warning is issued to the driver.

The main expected benefits from BLIS were to prevent lateral accidents between a vehicle leaving its own lane and an obstacle (e.g., other vehicle) travelling, in the same direction of travel, in the lane next to it.

Over 425 900 km were used in the hypothesis testing for BLIS.

**Main function boundary conditions common to all OEMs**

**Demographical requirements/ driver requirements**

n/a

**Geographical requirements/ road context**

n/a

**Geographical requirements/ environmental restrictions**

This function should not be sensitive to temperature, humidity, and air pressure. However, if the system implementing this function relies on cameras, then heavy rain, snow, fog, reflex from wet surfaces, sunlight may limit the function performance.

**Other limitations**

Function is active above 10 km/h.

The system is able to detect other objects with a relative speed above 10 km/h and below 70 km/h.

### 3.6 CSW

A list of partners involved in collecting CSW data is as follows:

<table>
<thead>
<tr>
<th></th>
<th>Ford</th>
<th>MAN</th>
<th>VOLVO</th>
<th>VCC</th>
<th>VW</th>
<th>CRF</th>
<th>IFSTTAR</th>
<th>BMW</th>
<th>DAG</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Function description**

CSW technology has been developed with the goal of identifying these potential dangerous situations, and warning the driver in advance, which allows him to react appropriately.
Based on the specific experimental design for the CSW (no baseline phase) an assessment of the safety benefit was not possible. The analysis of the CSW was mainly focused on the impact on driver related aspects based on subjective data.
4 Identifying changes in safety-related measures between baseline and treatment

In this chapter, the results of different hypotheses, organized by function, are presented in sections. Cars and trucks are treated separately. In the beginning of each section, the potential benefit of that function is presented together with relevant information in order for the reader to put the results into perspective. Further details regarding methodology can be found in deliverable 6.2.

In addition, in order to avoid the publication of partners’ proprietary information and to exclude benchmarking between different functions, results from the German1 and Swedish VMC were combined for the bundle ACC+FCW.

4.1 Hypotheses results for cars

4.1.1 ACC+FCW

In this sub-section we first offer an overview of the data selection in the ACC+FCW analysis, followed by a short discussion on usage. We then provide the potential benefit of ACC+FCW and, finally, the results of each individual hypothesis.

Results are presented as a combination of data from the Swedish (VCC) and German1 (Ford and VW) VMC’s. Rather than performing the analysis on a combined dataset, integration of different VMC’s was done at the result level, using a weighted average, weighted by total mileage per VMC. Thus, parameters such as p-value or standard error cannot be consistently calculated. Nevertheless, except when mentioned, results are statistically significant.

Data selection

Our first attempt to evaluate the benefit of ACC+FCW was a straightforward comparison of the entire treatment and baseline periods. With this approach, we found no change in most safety-related measures, suggesting the bundle had no effect on driver and vehicle behaviour. However, a further analysis indicated that drivers were not using ACC+FCW all the time in the treatment phase. Depending on road type, usage was at most 50% (motorways), and less for other road types. Thus for the first analysis it was impossible to tell whether the similarity between baseline and treatment was due to a limited system impact on driver/vehicle behaviour or a limited usage in proportion to the full data set. An analysis framework that addressed system usage and system impact on safety indicators independently was needed.

The first idea was to see if enough drivers with high usage of the bundle in treatment were available. If so, one could have analysed the data for these drivers alone and ignored low usage drivers. However, this turned out not to be possible for the euroFOT data. The next idea was to filter both baseline and treatment to exclude data where we expected function usage to be low. Filters that excluded driving on roads with less than a certain posted speed, that included only car following driving, and that excluded driving with less than a certain vehicle speed were tested. However, neither of these filters led to a significant increase in usage levels within the selected data (still below 50% on average for all data).

The third approach explored, which also was the one we decided to adopt in the project, was to exclude all treatment data in which ACC was OFF. This had the advantage that it ensures 100% usage in the treatment portion of the analysed data. However, it causes another problem: the driver selection bias. Since ACC+FCW usage is self-paced by drivers, the baseline data should principally be selected to include only driving where the drivers would
have opted to use ACC+FCW, had they had it available. Defining filters for selecting data that follows this principle is very complicated and might be impossible, as it involves second guessing driver behaviour. However, we chose to adopt a set of filters that we think approximate the most appropriate baseline data selection possible, given the data available. These filters, which were applied to both baseline and treatment data, and their effect in equalizing the driving conditions, are described in the following.

**Car following filter:** In terms of safety, ACC+FCW is mainly targeted towards reducing the number and severity of rear-end crashes. Hence, only data from driving when a lead vehicle was present in front of the equipped vehicle was included.

**Posted speed filter:** data in speed limits in which ACC was not used very often (usage below 25%) were discarded.

**Vehicle speed filter:** When approaching roundabouts and larger intersections, drivers normally brake. As this automatically disengages ACC and hence inevitably excludes this data from the treatment set (ACC ON), it follows that it had to be removed from baseline as well. A simple way of tackling this issue is to set a limit on minimum vehicle speed. Drivers typically enter roundabouts and larger intersection with speed equal to or below 50km/h, so by setting a minimum vehicle speed of 50km/h, most of such junctions and roundabouts were removed from both baseline and treatment periods. Note that FCW could still prevent incidents inside junctions, but this effect was disregarded since only data in which ACC and FCW were active together are being analysed.

**5 seconds wait-and-see filter:** as mentioned above, ACC disengages at braking. This means that harsh braking and critical time-gap events that happen right after ACC disengages would not be included in treatment if the ACC ON filter was strictly applied in treatment. To compensate for this, treatment data was selected to include five additional seconds each time ACC disengaged, to make sure these this type of events were coupled to ACC usage and not excluded from the treatment data.

To verify that the traffic conditions in baseline and treatment indeed were equalized and comparable when these filters were applied, vehicle speed and traffic density within filtered baseline and treatment were compared. Traffic density was calculated based on time headway and the ratio between posted speed and vehicle velocity for Germany and based on the number of vehicles per second in the same direction of travel with the subject vehicle for Sweden.

Results show that average vehicle speeds changed very little in treatment, i.e. when ACC+FCW were in use (+1.99% on motorways, where most of the data were concentrated), as shown later in the average speed hypothesis. As for traffic density, the density distribution is very similar in both periods, as shown in Figure 2 for Germany and Figure 3 for Sweden. From this we concluded that removing the selection bias altogether is most likely not feasible, but we believe our set of filters give a reasonable approximation and are therefore able to equalize traffic conditions in baseline and treatment sufficiently not to bias the outcome for the safety-related measures we tested.

The final data selection for cars included: expected speed above 60km/h, vehicle speed above 50km/h, and car-following situations. In addition, five seconds were added after ACC shut off. *Expected speed* is a map data variable very close to the posted speed of the road, but a few km/h below. It was used instead of posted speed due to the higher coverage in our data.
Note that these data selection criteria differ from the ones used in the Traffic Efficiency impact assessment, which likely explains the slightly different findings on average speed in D6.5/6.6.

Figure 2: Traffic density comparison in filtered baseline and treatment for ACC+FCW (cars in Germany). Note that the Treatment data is not missing. Baseline and Treatment are simply so similar that the Treatment markers and line become hidden behind the Baseline markers and line in the graph.

Figure 3: Traffic density comparison in filtered baseline and treatment for ACC+FCW (cars in Sweden). Note that the Treatment data is not missing. Baseline and Treatment are simply so similar that the Treatment markers and line become hidden behind the Baseline markers and line in the graph.

Usage
A short analysis of the situations under which ACC+FCW was used was conducted (Figure 4). Usage was calculated in treatment after applying the filters on expected speed, car following, and vehicle speed, as explained earlier. On average, ACC usage was 51% on motorways, 31% on rural roads, and 19% on urban roads.
Final results: Impacts on traffic safety
Figure 4 indicates that drivers have a strong tendency to use ACC+FCW during low traffic density on motorways (more than 50% of the time). On other road types, this effect is smaller. An analysis of the other situational variables also suggests that drivers tend to use the bundle in more favorable environmental conditions (bright, no rain, warm temperatures); however, this tendency is not very strong.

**Overview of the potential benefit**

The ACC+FCW function is intended to support the driver in selecting and maintaining an appropriate speed and time-headway depending on his/her preferences. Furthermore, ACC+FCW is intended to decrease driver response times in lead vehicle conflicts by issuing collision warnings, thus potentially reducing the risk of rear-end conflicts.

Overall, the bundle was expected to have a positive effect on both comfort and safety. The comfort side was mainly assessed subjectively with questionnaires in deliverable D6.3, while the potential safety benefits are addressed here.
Figure 5: Overall benefit of ACC+FCW on motorways (passenger cars). Numbers above bars indicate the relative change (positive or negative) between baseline and treatment for each indicator. These numbers can be read as percentages as well (i.e. 0.16 = 16%)

Figure 6: Overall benefit of ACC+FCW on rural roads (passenger cars). Numbers above bars indicate the relative change (positive or negative) between baseline and treatment for each indicator. These numbers can be read as percentages as well (i.e. -0.45 = -45%)
In Figures 5-7, the overall results in terms of relative change between baseline and treatment is given for a number of safety-related measures, divided by vehicle and road type respectively. Note that a relative change in one indicator may not be straightforwardly comparable to the relative change in another. However, the general idea of Figures 5-7 is to illustrate the common trends among the measures. Most importantly, in all figures, it is clear that the frequency of critical events decrease in treatment, regardless of how those critical events were defined.

Based on the overall results for ACC+FCW in cars, as displayed in Figure 5 to Figure 7, it can be concluded that when drivers use ACC+FCW, there is a positive effect on safety-related measures. There was no decrease in average speed (an indicator previously linked to increase in safety by Nilson, 1981), but the safety margins to the lead vehicle increased significantly when ACC+FCW was being used. Average time headway (THW) showed an overall increase of about 15%, and the frequency of critical THW's was reduced by 63% in urban areas, 81% on rural roads, and 73% on motorways. One possible contributing factor to the average THW increase is the fact that the selectable ACC time-headway settings can never be lower than the legally prescribed value, a limit that is not always respected in baseline driving.

Another way of assessing whether the safety margins actually increase in treatment is to look at braking behaviour. Essentially, if margins are greater, the need for more extreme braking manoeuvres should decrease. In principle, when drivers have more time to respond, the need for harsh braking is decreased. Following this, the evaluation of the number of harsh braking manoeuvres is also considered relevant to assess the safety benefit of the ACC+FCW. Results conform to this line of reasoning. For example, for motorway the reduction of these events is not quite as high as the one of critical time-headways, but one can say that two out of three harsh braking events occurring in the baseline were avoided by the use of the ACC+FCW bundle.

To evaluate the contribution of each individual function the reductions within phases where only one single function was activated were evaluated. Figure 8 shows the frequency of harsh braking events for the baseline and treatment phase depending on different

---

Figure 7: Overall benefit of ACC+FCW on urban roads (passenger cars). Numbers above bars indicate the relative change (positive or negative) between baseline and treatment for each indicator. These numbers can be read as percentages as well (i.e. 0.15 = 15%)
combinations of activation states of ACC and FCW for passenger cars. It can be seen in Figure 8 that the highest reduction in the treatment can be found in phases where the ACC was active, and that level of harsh braking events stays nearly the same in phases with FCW on and ACC off. Hence, the positive effect of the ACC and FCW bundle on harsh braking manoeuvres can be mainly attributed to the ACC.

Figure 8: Harsh braking events in baseline and treatment with consideration of ACC and FCW activation phases (passenger cars).

In Figure 9 a further effect of ACC on the number of FCW is shown. The comparison between baseline and treatment ACC active shows that the number of warnings issues by the FCW is reduced significantly by 79.6%. For the comparison to treatment ACC off a not significant increase of 17.9% was determined.

Figure 9: Number of FCW warnings in baseline and treatment on motorways (passenger cars).
We also observed a reduction both in kinematically derived and video annotated incident frequencies. While the incidents based on the video annotation include the individual rating based on subjective assessment (described in Annex 1: Video annotation in euroFOT), the kinematic related incidents evaluate the measurements of the vehicle dynamics and compare those to predefined thresholds. The following indicators are used to determine incidents based on vehicle kinematics. More details can also be found in (Benmimoun, M. et al, 2011):

- Longitudinal acceleration
- Lateral acceleration
- Yaw rate
- Status ABS/ ESP
- Time-headway (THW)
- Time to collision (TTC)

The incidents based on vehicle kinematics show more than 80% reduction while the video-based analysis showed over 30% fewer incidents when using ACC+FCW on motorways. The decrease in the latter was however not statistically significant. This is likely due to the fact that the final number of video annotated critical events judged relevant for ACC+FCW was very small. This in turn is due to the fact that crash relevant events and near crashes are truly rare events. For the current analysis, a total of 5.5 MM was spend on video reviewing over 1200 potential conflicts selected based on different kinematic threshold trigger criteria. Of these, only 68 were judged to be actual longitudinal crash relevant events, and hence retained for the analysis. This is indeed a very large reduction from the original 1200 events; on the other hand did noone expect all 1200 of those to be crash relevant, since the selection thresholds were quite liberal in to make sure all “real” events made it into the review list. However, the question naturally arises as to which event selection approach gives the “truest” results. Unfortunately, the answer to that question remains open (see Section 2 – Methodological concerns).

We also investigated hypothesized negative side effects of ACC+FCW in terms of increased secondary task engagement, attention to forward roadway and drowsiness. Given that ACC+FCW was expected to lower driver workload, one could hypothesize that secondary task engagement might increase, that visual attention to the forward roadway might decrease and that drowsy driving might increase.

According to these results, a number of interesting effects can be seen. First, during normal driving, car drivers were likely to engage in secondary tasks more often when using ACC+FCW. More specifically, while using ACC+FCW car drivers were three times more likely to engage in visual secondary tasks (e.g., reading maps, looking at passengers or objects in the car), compared to baseline. However, during crash relevant events, no such difference in secondary task engagement was found. This suggests that drivers are capable of adjusting secondary task engagement to situations where safety is not compromised. Moreover, driver’s attention towards the forward roadway during crash relevant events was higher in treatment. This suggests that the ACC+FCW function is successful in redirecting driver attention toward the forward roadway through the warnings it issues in critical events. Keep in mind though that the crash relevant event analysis is based on a comparatively small number of events, and hence to be viewed as a trend more than a solid fact. Lastly, there was no difference between baseline and treatment in terms of drowsy trip frequencies; hence, ACC+FCW presence does not seem to affect the amount of drowsy driving undertaken.

Concerning the risk matrix approach, simulation results show that there is a positive effect on the risk modification factor in treatment when no filtering was considered (whole treatment). When removing portions with ACC off from treatment, mixed results were obtained (risk
modification factor below and above one). This effect might be explained by an increased average speed when using ACC.

To make a prediction on an estimated benefit range for ACC+FCW, expert judgment was employed, based on a combination of the overall FOT results and previous knowledge from each VMC on the studied systems. The following procedure was adopted: as a low benefit boundary, the reduction in video-review based incidents (32%) was used for all road types. Using this number is a bit of a balancing act. On the one hand, the hypothesis testing for these incidents was not statistically significant and as such only indicates a trend. On the other hand, it does point in the same general direction as the other event based indicators, and we also believe it serves as the best guideline we have for predicting a reduction of extremely risky situations. It is the only indicator in the study where the full driving context can be taken into account when judging how serious, or near a crash, any particular situation is. For the upper bound, the reduction in the number of kinematic incidents was adopted where available, i.e., for motorways (81%). This incident type addresses a broader range of situations with where the precise level of risk involved is harder to assess, and thus leads to a less conservative reduction estimate. For urban and rural roads, the reduction in harsh braking events was used (rural: 45%, urban: 32%), since this indicator is the closest we have for these road types to the extreme kinematic conditions detected by the kinematic incident trigger.

Multiplying the estimated benefit range by usage gives us the reduction in the target crash population (rear end crashes that occur within the operational scope of ACC+FCW, see chapter 6) if ACC+FCW were fully deployed. Table 3 summarizes the results.

<table>
<thead>
<tr>
<th>Road type</th>
<th>Usage</th>
<th>Estimated range benefit</th>
<th>Potential reduction in the target crash population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motorway</td>
<td>51%</td>
<td>32 - 81%</td>
<td>16 - 42%</td>
</tr>
<tr>
<td>Rural</td>
<td>31%</td>
<td>32 - 45%</td>
<td>10 - 14%</td>
</tr>
<tr>
<td>Urban</td>
<td>19%</td>
<td>32%</td>
<td>6%</td>
</tr>
</tbody>
</table>

It should be stated that it is impossible to consider more than a small part of the available information when performing this type of analysis, and it is possible that our selection has constrained our interpretation of the safety benefit in ways difficult to predict. Nevertheless, we believe the final dataset used was a good compromise between taking into account uncontrolled factors and being general at the same time. Moreover, the euroFOT dataset will be available for further in depth analysis that was not possible within the project timeline.

Conclusions in a nutshell

In summary, it can be said that the combination of ACC and FCW can have a positive effect on safety-related measures based on the data gathered in the FOT. This positive effect can be attributed to changes in the distance behaviour while driving with active ACC and FCW. Due to the predefined settings of the ACC time-headway the number of (intended or unintended) close approaching manoeuvres is highly reduced and prevents therefore critical driving situations. If in addition the driving situation exceeds the braking capacities of the ACC because of a highly decelerating vehicle in front the presented warnings (by the ACC and the FCW) give the driver appropriate time to react on the driving situation.

In the following, hypotheses results are presented individually.
4.1.2 LDW+IW

In this sub-section we first offer an overview of the potential benefit of LDW+IW, followed by the results of each individual hypothesis. Results come from the Swedish VMC (VCC only).

Data selection

The analysis of LDW+IW in cars was done for all type of roads but limited to the operative range of the functions, which means that all driving that took place at speeds below 65 km/h was excluded, as was all driving where the lane markings were not visible. The limited the analysed dataset to driving in which the function could be, and actually was, used.

In the treatment data, portions of the data in which LDW+IW was not active were filtered out in order to focus the analysis on LDW+IW-related driver behaviour. This filtering might have introduced a bias in the analysis, since it is the driver who selects when to use and not use LDW+IW. One way of addressing this is to check whether this lead to different levels of traffic density in the baseline and the treatment data set. Figure 10 shows that there are no major differences between density distributions in the two periods, what suggests that the selection bias was satisfactorily reduced. Concerning usage, no major preferences were observed and, except for zones outside the function’s operative range, LDW+IW was on most of the time.

Figure 10: Traffic density comparison in filtered baseline and treatment for LDW+IW (cars). Note that the Treatment data is not missing. Baseline and Treatment are simply so similar that the Treatment markers and line become hidden behind the Baseline markers and line in the graph.

Overview of the potential benefit

The LDW+IW function was expected to support the driver in avoiding unintended lane departures, either due to distraction (LDW) or drowsiness (IW). Overall, the bundle was expected to have a positive effect on both comfort and safety. The comfort side was mainly assessed subjectively with questionnaires in D6.3, while the safety benefits are addressed here.

Based on the overall results for LDW+IW in cars, displayed in Figure 11, it can be concluded that some of the indicators point toward a potential increase in safety when drivers use LDW+IW. The mean steering wheel angle was slightly reduced and use of turn indicators increased, both of which may indicate improved lateral control. Also, results show that LDW issues warnings mainly when drivers are not looking at the road ahead. Hence, it may address potentially unsafe situations. The frequency of a lateral crash relevant events also decreased when using LDW+IW, but that decrease was not statistically significant. This might be because the number of annotated events judged as relevant for LDW+IW was small. Crash relevant events and near crashes are rare events. A total of 5.5 MM was spent on reviewing over 1200 potential conflicts based on video and kinematic data. From this
dataset, only 133 were judged to be truly relevant lateral events, and hence retained for the analysis.

We also investigated possible negative side effects of LDW+IW in terms of secondary task engagement, attention to forward roadway and drowsy trip frequency. Results showed some interesting effects related to LDW+IW in the first two measures. First, during normal driving, the likelihood of the driver using a nomadic device increased when drivers were using LDW+IW. However, during crash relevant events, no such increase was found. Many potential explanations for this exist and further investigation would be necessary to settle on anyone of those. However, at face value these results indicate that drivers seem capable of self-regulating nomadic device usage to situations that do not involve a potential increase in risk. This line of reasoning is supported by the fact that there was no difference in visual attention to the forward roadway during critical events in baseline and treatment.

Unfortunately, there is insufficient evidence to enable up-scaling of the safety impact of LDW+IW to EU-27 level. Since the difference in crash relevant events is not significant, there are only two indicators that show a significant difference between baseline and treatment (Mean Steering Wheel Angle and Turn Indicator Usage). Neither of these have a sufficiently strong connection to crash causation to suffice as a basis for up-scaling on their own. For example, lane keeping is not something that drivers optimize, i.e. they may "bounce" between lane markers rather than try to stay exactly in the center of the lane all the time. This makes the coupling between the average Mean Steering Wheel Angle and the risk of a lane departure (and hence a crash) weak. Furthermore, the decrease is small, i.e. it's approximately a tenth of a degree, where the typical range on all road types for this PI is 4-5 degrees.

It should be stated that it is impossible to consider more than a small part of the available information when performing this type of analysis, and it is possible that our selection has constrained our interpretation of the safety benefit in ways difficult to predict. Nevertheless, we believe the final dataset used was a good compromise between taking into account uncontrolled factors and being general at the same time. Moreover, the euroFOT dataset will be available for further in depth analysis that was not possible within the project timeline.

![Figure 11: Overall benefit of LDW (passenger cars). Numbers above bars indicate the relative change (positive or negative) between baseline and treatment for each indicator. These numbers can be read as percentages as well (i.e. -0.15 = -15 %)](image)

**4.1.3 Speed Limiter and Cruise Control (SL+CC)**

In this sub-section we offer an overview of the potential benefit of SL+CC. The results of each individual hypothesis can be found in Annex 3.
For the analysis, the French VMC adopted a chunking process, which consist of splitting the all trips according to certain values for situational variables. At the French VMC, the following variables were kept constant among chunks: TripID, DriverID, road type (Urban, rural, motorway), speed limit (30, 50, 70, 90, 110, 130 km/h), weather (dry or rain), and lighting (night or day). The process ends by obtaining thousands of 10 to 30 sec. chunks, where each one is characterised based on a list of performance indicators (PI’s). Further details can be found in the euroFOT deliverable D6.2, that also covers the following:

- Chunking process at the French VMC in more detail
- Statistical methods
  - Baseline sampling
  - Methods for aggregated based analysis (ABA)
  - Methods for event based analysis (EBA)

**Usage**

Figure 12 presents the ratios by which are multiplied the odds of observing an event of interest ("SL is active" and "CC is active" for instance) when binary situational variables are varying from one condition to another. The odds can be viewed as the likelihood of observing the event under a specific condition. For example, when it is raining, the likelihood of using SL is multiplied by 1.4 than in dry weather conditions (odds ratio = 1.4). It is the opposite for CC which is less likely to be used: the likelihood is multiplied by 0.6 (odds ratio = 0.6).

![SRS Odds Ratio for situational variables](image)

*Figure 12: Odds ratios corresponding to the event "SL is active" (resp. "CC is active") for different binary situational variables.*

**Overview of the potential benefit**

**Average speed**

The SL increased the average speed (differences range between 0,75 to 2,33km/h) except on motorways (better compliance with speed limit).

The CC increased the average speed when used. Differences between treatment and baseline are 7,9 km/h on 130km/h roads, and 12,6 km/h on 110 km/h roads.
Over speeding occurrences

The effects of the SL on the over speeding events are greater for high speed limits, with a reduction of up to 50% when using the system.

From 50 to 110km/h limited roads the likelihood of exceeding the speed limit while using the CC are two to four times the likelihood of exceeding the speed limit under normal conditions (without using any system). The effect of CC increase the probability of exceeding the speed on most roads, but the effect is opposite on motorways (OR=0,77). High speeds (like 130km/h) seem to be sufficient for a French driver, or the risk of being controlled is estimated to be higher on motorways, leading to a better compliance with the speed limits.

Strong jerk occurrences

The SL has a positive effect (reduction of the probability of observing a strong jerk event) although it is small and not significant under many conditions.

For CC, results are significant for all road types, showing a clear positive influence of the CC on the probability of observing a strong jerk event while driving. The probability of observing this kind of event is approximately reduced by a factor of 3 when using the system.

Critical time gap occurrences

At 50 km/h, the SL system multiplied by 1.13 the likelihood of observing a critical time gap event when driving with the system compared to normal conditions. The same negative impact is observed on 130km/h limited roads, with a likelihood of observing a critical time gap event when driving with the system compared to normal conditions multiplied by 1.3. Other conditions were not significant.

The ability of the CC to modify critical time gap occurrence probability was significant for all the speed limits. On 50 km/h roads, the CC system multiplied by 0.31 the likelihood of observing a critical time gap event when driving with the system compared to normal conditions. The same positive impact is observed for all the speed limits, although the effect is less important for high speed limits.

Hard braking occurrences

The SL system effect on hard braking occurrences was positive, with people using the system having a reduction of the likelihood of approximately 30%.

The ability of the CC system to modify hard braking occurrence probability is significant for all roads except 30km/h roads (not enough data to ensure representativeness). The CC system effect on hard braking occurrences is positive, with people using the system having a reduction of the likelihood of approximately 50%.

Incident occurrences

Results of the ANOVA did not show any significant effect among the three factors. There is no significant difference in the incident rate between baseline and treatment. We looked more precisely at situations where system is active and adopted an EBA. The likelihood of the incidents decreased significantly when driving with SL or CC active. The estimated decrease in incident rate is more important for CC (SL: OR=0,683; CC: OR=0,165).

This last effect may be due to driver’s choice to use the system when traffic is free flowing instead of the system effect itself. This effect is higher for CC usage, leading to an apparently strong positive effect, although this should likely not be credited to the system itself but to the driver’s choice to use it depending on the surrounding traffic situation.
4.1.4 Navigation System

In this sub-section we first offer an overview of the potential benefit of the Navigation System, followed by the results of each individual hypothesis.

Overview of the potential benefit

In the questionnaires drivers indicate that they did not like the mobile navigation system and that they also did not trust it as much as they trusted the built-in device. This evaluation is not only based on the differing HMI-solutions but also on the basic functionality of the systems. The mobile device is experienced as less reliable and also as giving sometimes the wrong routing information or as choosing inefficient routes (for more details see D6.3). Further analysis of objective system usage shows that the usage of a navigation system depends on the familiarity of a trip and on trip length. The navigation system is activated more often on long and on unfamiliar trips. The mobile device is used less often than the built-in device especially in situations where overall system usage is less likely (short trips, unfamiliar trips).

![Figure 13: Proportion of trips with active navigation system separate for familiarity of route and trip length. The graphs show means and standard deviations.](image)

To assess whether navigation systems help the driver to choose more efficient routes, the measured travel time and travel distance were compared to an estimated travel time and distance provided by a reference route planner. With that approach it has been tried to reduce error variance due to differing trips made in the three conditions. Results show that both systems reduce travel time compared to driving in the baseline condition (no navigation system available) by 7% to 9%. The effects on travel distance differ for the two systems and are probably influenced by characteristics of the routing algorithms used (for more details see D6.5). Note also that while the graphs in D6.3 may indicate that time spent in congestion increases with the built in device, this is an effect of the graphs only showing the means and not the confidence intervals. Statistical tests show no significant effect of any of the two tested systems on time spent in congestion.

Regarding potential direct safety effects of navigation systems, they are expected to be most pronounced directly before or at intersections. Here, the systems provide routing information in a timely manner when approaching turning points. As a consequence, on or close to intersections navigation systems might help to adjust driving behaviour in time and to manage to drive smoothly through intersections with greater anticipation. Furthermore, at intersections where the driver is unsure about if and where to turn, the routing information might reduce driver load and as a consequence the driver might be able to focus more on passing the intersection safely because he / she does not need to search for the correct path.
Based on the described mechanisms, a potential safety benefit of navigation is expected at or prior to intersections. The analysis of direct safety effects will be restricted to urban and rural areas. Highways are not considered because navigating is less complex and less demanding. Furthermore, on highways it is more difficult to limit the analysis to points in time where drivers need to decide about which way to take. If we limit the analysis to highway exists actually taken by the driver, only a very small data set remains that does not allow to reliably estimate the direct safety benefit of navigation systems. If we take all highway driving into account, the part of the analysed data set in which a navigation system could directly influence driving safety it too small. For urban and rural roads, Table 4 shows the proportion of time in which drivers used the routing function of the navigation system split for urban and rural areas.

<table>
<thead>
<tr>
<th>Table 4: Proportion of time driving with navigation system active on urban and rural roads.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Built-in device</td>
</tr>
<tr>
<td>Mean</td>
</tr>
<tr>
<td>Rural</td>
</tr>
<tr>
<td>Urban</td>
</tr>
</tbody>
</table>

Several safety indicators are analysed. The incident frequency per intersection is considered the main safety indicator for the following reasons:

1. Incident frequency combines thresholds based on THW, TTC, longitudinal and lateral acceleration.
2. It is the only indicator that is calculated per intersection crossed. Therefore, it can be directly related to the assumed safety mechanism of a navigation system.

The incident frequency is analysed for the overall sum of incidents per intersection and split for the following incident types:

1. Distance events: THW or TTC criteria are fulfilled
2. Longitudinal events: hard braking or ABS activation
3. Lateral events: criteria for lateral acceleration or yaw rate are fulfilled

For urban and rural roads, other safety indicators are analysed as well. All of the following indicators are not analysed per intersection but per hour of driving on rural or urban roads.

4. Proportion of time with critical time-head-way THW (<0.5 sec)
5. Proportion of time with critical time-to-collision TTC (<1.75 sec)
6. Number of hard braking events
7. Proportion of time with critical time-to-line-crossing TLC (<1 sec)
8. Frequency of lane exceedances
The safety benefit in percent is only quantified for the sum of incidents. For other indicators, qualitative findings are reported as significant results (p<0.05; -- / ++) (reduction and increase, respectively) and tendencies (p<0.1; - / +) (reduction and increase, respectively) are reported (see Table 5). Empty cells show that the indicator has been tested but that there is no statistically significant result. The overall picture helps to judge, whether results for incidents are reliable.

### Table 5: Overall benefit of the Navigation System

<table>
<thead>
<tr>
<th>PI</th>
<th>Change</th>
<th>Rural</th>
<th>Urban</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Built-in Device</td>
<td>Mobile Device</td>
</tr>
<tr>
<td>Incidents at intersections</td>
<td></td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-5.4%</td>
<td>-21.5%</td>
</tr>
<tr>
<td>Critical THW</td>
<td></td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Critical TTC</td>
<td></td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Hard brakings</td>
<td></td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Critical TLC</td>
<td></td>
<td></td>
<td>--</td>
</tr>
<tr>
<td>Lane exceedances</td>
<td></td>
<td></td>
<td>--</td>
</tr>
<tr>
<td>Hard accelerations</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

For urban roads, the decrease in the overall incident frequency can also be found if it is tested separately for all three incident types. As can be seen in Table 5 for the built-in device a safety benefit cannot only be found in a reduction of incidents at intersections. It is also reflected in decreases of critical distances, hard braking events and lane keeping errors on urban roads. Compared to that, the decrease of incidents for the mobile device is a less global effect. For the other safety indicators, only the reduction of critical distances is significant.

It is expected that the familiarity of a trip might influence the effects of navigation systems. In a first step, the incident frequency is compared for familiar and unfamiliar trips in the baseline condition (no navigation system available). That comparison shows a significantly lower incident frequency on unfamiliar trips for rural and urban roads (rural: chi² = 3.44, p<0.001, urban: chi² = 3.51, p<0.001). One interpretation of that result is that driving is more cautiously if drivers are unsure about which way to take.

If we conduct the above presented analysis of direct safety benefits of navigation systems again, now split for familiar and unfamiliar trips, the results shown in Table 6 can be found.
Table 6: Benefit of the Navigation System with separate analyses for familiar and unfamiliar trips
PI = performance indicator.

<table>
<thead>
<tr>
<th>PI</th>
<th>Situation</th>
<th>Change</th>
<th>Familiar</th>
<th>Unfamiliar</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Built-in Device</td>
<td>Mobile Device</td>
</tr>
<tr>
<td>Incidents at intersections</td>
<td>Rural</td>
<td>-7.8</td>
<td>-50.1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Urban</td>
<td>-8.1</td>
<td>-52.6</td>
<td>0</td>
</tr>
<tr>
<td>Critical THW</td>
<td>Rural</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Critical TTC</td>
<td>Rural</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Critical TLC</td>
<td>Rural</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Lane exceedances</td>
<td>Rural</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Critical THW</td>
<td>Urban</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Critical TTC</td>
<td>Urban</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Critical TLC</td>
<td>Urban</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Lane exceedances</td>
<td>Urban</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>

As can be seen, the significant decrease of incidents is based on familiar trips only. Again, the safety benefit is more global for the built-in navigation system. This is also the only of the two systems for which in some safety indicators a significant safety benefit can be found for unfamiliar routes, too.

As can be seen in Table 7, the drivers spent between 70% and 80% of their travel time on familiar routes. Due to that, the results for unfamiliar trips are based on less data than the results for familiar routes. This does not only relate to the basic mileage used for the analysis but also to the number of drivers that could be included in the statistical testing.

Table 7: Proportion of travel time spent on familiar trips for urban and rural roads.

<table>
<thead>
<tr>
<th>Proportion fam. travel time</th>
<th>mean</th>
<th>Confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rural</td>
<td>75.9%</td>
<td>[71.0%; 80.7%]</td>
</tr>
<tr>
<td>Urban</td>
<td>80.1%</td>
<td>[76.2%; 83.9%]</td>
</tr>
</tbody>
</table>

Taking the results for familiarity into account, the interpretation that the safety benefit observed in the overall testing is caused by the navigation system gets difficult. Both results are not in line with the assumption that because of the routing information drivers need fewer resources for way finding and therefore can concentrate more on navigating through intersections safely. If that was true, one would expect that unfamiliar trips are less safe than familiar ones in the baseline condition and that the safety benefit mainly occurs on unfamiliar trips. Instead, one possible interpretation is that driving gets more cautiously if drivers are not so familiar with a route. This need not only be unfamiliar trips but also rare but familiar ones (e.g. going once or twice a year). At the same time, these are trips on which the usage of a navigation system is most likely. In that case, the observed safety benefit would not be because of the navigation system but because of some very hard to control moderating factor.
Besides the hard to explain direct safety effect, an indirect safety effect of navigation systems can be found. Because navigation systems help the driver to successfully shorten travel times, the overall exposure to potential accident involvement is lower if drivers use a navigation system. Again, this effect is very difficult to upscale because overall statistics of accidents are based on mileage but not on travel time.

Looking at the differing results for the two HMI-solutions, the results for the mobile device seem less reliable than the results for the built-in navigation systems. As can be seen in the performance indicators used, the reduction of incidents for the mobile device is based on critical distance only. In the other indicators, no significant effect of the mobile device can be found. This is different for the built in system. Here, a change in safety related indicators can be found in all used PIs. In addition, drivers rated the mobile device as less favourable and used it less than the built in device. If we assume that incidents are rare events, chances to detect at least one incident rises with analyzed measurement time. Because several drivers used the mobile device very little, quite a few had no incidents at all in the condition mobile device. Therefore, the safety results for the mobile device are based on a smaller set of data with system active. Furthermore, it is also possible that drivers try to compensate for the expected errors of the mobile device by driving overcautiously.

Based on the results from the FOT, it can be concluded that when navigation systems are activated there are positive effects on potentially safety relevant indicators. Whether this is caused by the navigation function or by some other uncontrolled moderating factor cannot be concluded. Since safety benefits of navigation systems are not reported in the literature and also because no experiment is known which investigates possible mechanisms through which a navigation system might support driving safety, it is very difficult to judge whether the measured effects can be generalized or whether the safety benefit is based on mechanism specific for the conducted FOT. Because the safety mechanism for the navigation systems is not known, a potential safety benefit caused by navigation systems needs further investigation. As a consequence, up-scaling of the measured safety benefit is not considered to be reliable.

4.1.5 BLIS

In this sub-section we first offer an overview of the potential benefit of BLIS, followed by the results of each individual hypothesis. Results come from the Swedish VMC (VCC only).

Data selection

The analysis of BLIS in cars was done for all type of roads but limited to the operative range of the function, which means that vehicle speed needs to be above 10 kph. The intent was to limit the dataset to situations in which the function could be, and actually was, used.

In the treatment data, it quickly became clear that LDW and BLIS to some extent overlap in their functionality, at least when it comes to more or less intended lane changes on multilane roads. The analysis was therefore focused on the portions of data where LDW was switched off, i.e. not activated by the driver. This filtering might introduce a bias in the analysis, since it is the driver who selects when to use and not use LDW and BLIS respectively. However, in order to understand the influence of BLIS, we believe that the data selection as described above was necessary.

Overview of the potential benefit

The BLIS function was expected to support the driver in avoiding initiating lane changes when there is a vehicle in the adjacent lane, in particular when that vehicle cannot be seen through the regular rear view mirrors. Overall, the function was expected to have a positive effect on both comfort and safety. The comfort side was mainly assessed subjectively with the questionnaire data (see D6.3), while the safety benefits are addressed here.
In terms of the relative frequency of crash relevant events, very few BLIS relevant incidents could be identified in the data (< 10 events). Hence no significant differences between baseline and treatment could be identified.

The use of turn indicator decreased by, approximately, 10% when BLIS was in use. This is an interesting contrast to the LDW+IW findings, which indicate the opposite, i.e. a 10% increase in turn indicator use when LDW+IW is in use. These results are not contradicting however, since the BLIS data studied was selected from the portions of treatment driving when LDW+IW was switched off. Rather, they seem to reflect a clear case of driver adaptation. When LDW+IW are active, drivers use the indicators more to avoid the warning sound that they otherwise get if they change lanes without signalling. When BLIS is active, the questionnaire data confirms that drivers trust the system not to give false negatives (i.e. not warn even though there is a vehicle in the blind spot). Hence the need to use the turn indicator is reduced, because drivers perceive that they really know that there is no other vehicle in the lane they are changing into.

In terms of predicting a safety impact of BLIS to a regional/national or EU-27 level, there is unfortunately simply not enough solid results in the empirical data to base such an up-scaling on. No difference in crash relevant events could be identified, and the decrease in turn indicator usage alone is not a sufficient ground to base a prediction on crash involvement and injury outcome on.

4.1.6 Risk Matrix Approach (RMA)

This section describes the safety impact on rear-end crashes when using ACC+FCW, determined using the risk matrix approach. This risk matrix approach method is developed in euroFOT for the assessment of continuously operating functions, such as ACC and SRS. This risk matrix approach and the event based approach are complementary. The results below add a quantified view to the safety impact of ACC and FCW.

The results in this section are based on data from different types of vehicles from the manufacturers Ford and Volvo cars, driving mainly in Germany and Sweden. The results from different vehicles and vehicle types are weighted by mileage.

The risk matrix approach calculates predicted changes in conflict risk. These changes are called Risk Modification Factors (RMFs). RMFs are calculated by dividing the risk in treatment condition by the risk in the baseline under similar conditions. A RMF below one suggests that driving when using the function is safer than when not using the function.

The RMFs are calculated based on computer simulations of longitudinal vehicle conflicts. Monte Carlo simulations are performed to explore crash and injury risks in a wide spectrum of car following situations. The risk is then assessed by mapping the observed car-following behaviour in the FOT to the simulated risks. The method is described in more detail in euroFOT deliverable 6.2 Analysis methods for user related aspects and impact assessment on traffic safety, traffic efficiency and environment.

RMFs are calculated for different contextual situations, such as different road types, and for slight and severe injuries. RMFs could not be calculated for fatalities since the relation between impact speed and fatality could not be empirically determined due to the limited number of fatal rear-end accidents in the crash databases.

The presented results compare the RMF measured during baseline (driving without ACC+FCW) with (1) having ACC+FCW: the whole treatment and (2) using ACC+FCW: treatment with ACC on only. Note that this represents a quite different type of selection of baseline and treatment data than the one applied in section 5.1.1. Note also that the 5 seconds wait and see filter as described in section 5.2.1 was not applied here. Hence results might not be exactly comparable to those given in Section 5.1.1.
FOT Results

The effects of having ACC+FCW in vehicle, as measured in the FOT, are shown in Table 8 and Figure 14 in terms of the Risk Modification Factor.

The Risk Modification Factor is risk per km for the treatment divided by the risk per km for the baseline, so a risk modification factor below 1 suggests a potentially positive safety effect. Slight and severe injuries are based on categories of slight and severe injuries from the GIDAS crash database.

Also the mileage for baseline and treatment is presented. The results are provided separately for the different situations. A part of data could not be attributed to either one of the situations, and is reported under the category ‘unknown’.

<table>
<thead>
<tr>
<th>Table 8: Risk Modification Factor and mileage per situation for treatment versus baseline.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Situation</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>All situations</td>
</tr>
<tr>
<td><strong>Road type</strong></td>
</tr>
<tr>
<td>Motorway</td>
</tr>
<tr>
<td>Rural</td>
</tr>
<tr>
<td>Urban</td>
</tr>
<tr>
<td>Unknown</td>
</tr>
<tr>
<td><strong>Motorway + traffic state</strong></td>
</tr>
<tr>
<td>Free flow</td>
</tr>
<tr>
<td>Congestion</td>
</tr>
<tr>
<td>Unknown</td>
</tr>
<tr>
<td><strong>Weather</strong></td>
</tr>
<tr>
<td>Normal</td>
</tr>
<tr>
<td>Rain</td>
</tr>
<tr>
<td>Unknown</td>
</tr>
<tr>
<td><strong>Lighting</strong></td>
</tr>
<tr>
<td>Light</td>
</tr>
<tr>
<td>Dark</td>
</tr>
<tr>
<td>Unknown</td>
</tr>
</tbody>
</table>

The Risk Modification Factor for the all situations is not necessarily the weighted average of the Risk Modification Factors for the component situations. Note that, as opposed to the RMF, the Risk Factor (RF) does need to be a weighted average of the risk factors for specific situations. The RF is the risk per km for either baseline or treatment. In addition, the Risk Modification factor is determined by four parameters obtained from the FOT data, being the speed of the FOT vehicle, the speed of the predecessor, the time headway and the acceleration of the FOT vehicle.
FOT results considering system activation

Risk modification factors for system state ACC on are also calculated.

The effects of using in the vehicle, as measured in the FOT, are shown in Table 9 and in Figure 15 in terms of the Risk Modification Factor. The Risk Modification Factor is risk per km for the treatment divided by the risk per km for the baseline, so a risk modification factor below 1 suggests a positive safety effect.

Also the mileage for baseline and treatment is presented. The results are provided separately for the different situations. A part of data could not be attributed to either one of the situations, and is reported under the category 'unknown'.
### Table 9: Risk Modification Factor and mileage per situation for treatment ACC ON versus baseline.

**Risk modification factor and mileage per situation for treatment on versus baseline**

<table>
<thead>
<tr>
<th>Situation</th>
<th>Risk Modification Factor</th>
<th>Mileage</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Baseline</td>
<td>Treatment</td>
<td>ACC ON</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Injuries</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Slight</td>
<td>0.90</td>
<td>1.00</td>
<td>663788</td>
<td>100%</td>
<td>463030</td>
</tr>
<tr>
<td></td>
<td>Severe</td>
<td>1.00</td>
<td>1.00</td>
<td>663788</td>
<td>100%</td>
<td>463030</td>
</tr>
<tr>
<td><strong>All situations</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Road type</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motorway</td>
<td>0.75</td>
<td>0.76</td>
<td>217374</td>
<td>33%</td>
<td>243575</td>
<td>53%</td>
</tr>
<tr>
<td>Rural</td>
<td>1.05</td>
<td>1.17</td>
<td>244339</td>
<td>37%</td>
<td>148168</td>
<td>32%</td>
</tr>
<tr>
<td>Urban</td>
<td>0.96</td>
<td>1.19</td>
<td>191062</td>
<td>29%</td>
<td>83976</td>
<td>18%</td>
</tr>
<tr>
<td><strong>Motorway + traffic state</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Free flow</td>
<td>0.75</td>
<td>0.76</td>
<td>214740</td>
<td>32%</td>
<td>243147</td>
<td>53%</td>
</tr>
<tr>
<td>Congestion</td>
<td>0.98</td>
<td>1.21</td>
<td>2618</td>
<td>0%</td>
<td>423</td>
<td>0%</td>
</tr>
<tr>
<td><strong>Weather</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>0.90</td>
<td>1.00</td>
<td>578177</td>
<td>87%</td>
<td>409118</td>
<td>88%</td>
</tr>
<tr>
<td>Rain</td>
<td>0.89</td>
<td>0.99</td>
<td>85556</td>
<td>13%</td>
<td>53905</td>
<td>12%</td>
</tr>
<tr>
<td><strong>Lighting</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light</td>
<td>0.91</td>
<td>1.03</td>
<td>525091</td>
<td>79%</td>
<td>352661</td>
<td>76%</td>
</tr>
<tr>
<td>Dark</td>
<td>0.86</td>
<td>0.92</td>
<td>134257</td>
<td>20%</td>
<td>109617</td>
<td>24%</td>
</tr>
</tbody>
</table>

**Figure 15: Risk Modification Factor per situation ACC on versus baseline.**
Conclusion

Simulation results indicate a positive treatment effect on the Risk Modification Factors when no filtering was considered. However, when removing data with ACC off from treatment (similar to how treatment data was selected in Section 5.1.1), mixed results were obtained (RMFs both below and above 1). This contrasts to the overall results of the direct hypothesis testing on empirical data for safety-related measures (Section 5.1.1). Since RMFs are quite sensitive to speed changes, a possible explanation for this might be the small increase in average speed found in treatment with ACC+FCW active.
Hypotheses results for trucks

4.1.7 ACC+FCW

In this sub-section we first offer an overview of the data selection in the ACC+FCW analysis, followed by a short discussion on usage. We then provide the potential benefit of ACC+FCW and, finally, the results of each individual hypothesis.

Results are a combination of data from the Swedish (Volvo) and German1 (MAN) VMC’s. Rather than performing the analysis on a combined dataset, integration of different VMC’s was done at the result-level, using an average weighted by total mileage per VMC. Thus, parameters such as p-value or standard error cannot be consistently calculated. Nevertheless, except when mentioned, hypotheses results are statistically significant.

Data selection

Our first attempt to evaluate the benefit of ACC+FCW was a straightforward comparison of the entire treatment and baseline periods. With this approach, we found no change in most safety-related measures, suggesting the bundle had no effect on driver and vehicle behaviour. However, a further analysis indicated that drivers were not using ACC+FCW all the time in the treatment phase (usage below 40% on average). Thus for the first analysis it was impossible to tell whether the strong similarity between baseline and treatment was due to a limited system impact on driver/vehicle behaviour or a limited usage in proportion to the full data set. An analysis framework that addressed system usage and system impact on safety indicators independently was needed.

The first idea was to see if enough drivers with high usage of the bundle in treatment were available. If so, one could have analysed the data for these drivers alone and ignored low usage drivers. However, this turned out not to be possible for the euroFOT data. The next idea was to filter both baseline and treatment to exclude data where we expected function usage to be low. Filters that excluded driving on roads with less than a certain posted speed, that included only car following driving, and that excluded driving with less than a certain vehicle speed were tested. However, neither of these filters led to a significant increase in usage levels within the selected data (still below 50%).

The third approach explored, which also was the one we decided to adopt in the project, was to exclude all treatment data in which ACC was OFF. This had the advantage that it ensures 100% usage in the treatment portion of the analysed data. However, it causes another problem: the driver selection bias. Since ACC+FCW usage is self-paced by drivers, the baseline data should principally be selected to include only driving where the drivers would have opted to use ACC+FCW, had they had it available. Defining filters for selecting data that follows this principle is very complicated and might be impossible, as it involves second guessing driver behaviour. However, we choose to adopt a set of filters that we think approximates the most appropriate baseline data selection possible, given the data available. These filters, which were applied to both baseline and treatment data, and their effect in equalizing the driving conditions, are described in the following.

Car following filter: In terms of safety, ACC+FCW is mainly targeted towards reducing the number and severity of rear-end crashes. Hence, only data from driving when a lead vehicle was present in front of the equipped vehicle was included.

Posted speed filter: data in speed limits in which ACC was not used very often (usage below 25%) were discarded. For trucks, only limits above or equal to 100km/h were kept (motorway driving).
**Vehicle speed filter:** When approaching roundabouts and larger intersections, drivers normally brake. As this automatically disengages ACC and hence inevitably excludes this data from the treatment set (ACC ON), it follows that it had to be removed from baseline as well. A simple way of tackling this issue is to set a limit on minimum vehicle speed. Drivers typically enter roundabouts and larger intersection with speed equal to or below 50km/h, so by setting a minimum vehicle speed of 50km/h, most of such junctions and roundabouts were removed from both baseline and treatment periods. Figure 16 shows the cumulative sum of vehicle speed 10m before entering both roundabouts and large intersections. This figure indicates that, for example, drivers entered 90% of all large intersections with speed equal to or below 50km/h. A similar situation holds for roundabouts. Note that FCW could still prevent incidents inside junctions, but this effect was disregarded since only data in which ACC and FCW were active together are being analysed.

![Figure 16: Cumulative sum of vehicle speed 10m before junction.](image)

**5 seconds wait-and-see filter:** as mentioned earlier, ACC disengages at braking. This means that harsh braking and critical time-gap events that happen right after ACC disengages would not be included in treatment if the ACC ON filter was strictly applied in treatment. To compensate for this, treatment data was selected to include five additional seconds each time ACC disengaged, to make sure these this type of events were coupled to ACC usage and not excluded from the treatment data.

To verify that the traffic conditions in baseline and treatment indeed were equalized and comparable when these filters were applied, vehicle speed and traffic density within filtered baseline and treatment were compared. Traffic density was calculated based on time headway and the ratio between posted speed and vehicle velocity.

Results show that average vehicle speeds were within 1km/h of each other in baseline and treatment, (as shown later in the average speed hypothesis). As for traffic density, it was low or medium in 94% of baseline and 98% of treatment (Figure 17). From this we concluded that removing the selection bias altogether is most likely not feasible, but we believe our set of filters give a reasonable approximation and are therefore able to equalize traffic conditions in baseline and treatment sufficiently not to bias the outcome for the safety-related measures we tested.
The final data selection for trucks included: high speed roads (posted speed above 100km/h, motorways), vehicle speed above 50km/h, and car-following situations. In addition, five seconds were added after ACC shut off.

Note that these data selection criteria differ from the ones used in the Traffic Efficiency impact assessment, which likely explains the slightly different findings on average speed in D6.5/6.6.

![Traffic density distribution in filtered baseline and treatment for ACC+FCW (trucks)](image)

**Figure 17:** Traffic density comparison in filtered baseline and treatment for ACC+FCW (trucks).

**Usage**

A short analysis of the situations under which ACC+FCW was used was conducted (Figure 18). Usage was calculated in treatment after applying the filters on posted speed, car following, and vehicle speed, as explained earlier. On average, ACC usage was 42%.
Figure 18: ACC+FCW usage for trucks under different situational variables.

Figure 18 indicates that drivers used ACC+FCW almost 60% of the time when the traffic density was low. Usage during medium traffic density was below 30%, although the bundle could potentially be even more beneficial and increase comfort under heavier traffic. For the other conditions in Figure 18, there is no difference larger than 10%. It is interesting to note, however, that usage under adverse situations such as fog or cold temperature, are not significantly lower. This result is in line with the findings from subjective analyses pointing to a high driver trust on the bundle.

Overview of the potential benefit

The ACC+FCW function was expected to support the driver in selecting and maintaining an appropriate speed and time-headway depending on his/her preferences. Furthermore, ACC+FCW is intended to decrease drivers’ response times when lead vehicle conflicts occur by issuing collision warnings, thus potentially reducing the risk of rear-end crashes.
Overall, the bundle was expected to have a positive effect on both comfort and safety. The comfort side was mainly assessed subjectively with questionnaires in deliverable D6.3, while the safety benefit is addressed here.

Based on the overall results for ACC+FCW in trucks, displayed in Figure 19, it can be concluded that when drivers use ACC+FCW there is a positive effect on safety-related measures. Although we did not observe a decrease in average speed (an indicator previously linked to increase in safety by Nilson, 1981), the extended time headway and the reduced number of critical time-gaps significantly contribute to creating larger safety margins. Average time headway (THW) showed an overall increase of about 5% and the frequency of critical THW’s reduced by 54% on motorways. One possible contributing factor to the average THW increase is the fact that the selectable ACC time-headway settings can never be lower than the legally prescribed value, a limit that is not always respected in baseline driving.

Another way of assessing whether the safety margins actually increase in treatment is to look into braking behaviour. Results showed a decrease in the frequency of harsh braking events (37%), which can be linked to the increased time headway, i.e. when drivers have more time to respond, the need for harsh braking decreases.

In addition, we observed a reduction in both kinematically derived (36%) and video annotated incidents (14%). While the incidents based on the video annotation include the individual rating based on subjective assessment (described in Annex 1: Video annotation in euroFOT), the kinematic related incidents evaluate the measurements of the vehicle dynamics and compare those to predefined thresholds. Descriptions of the incident analysis types can be found in Benmimoun, M. et al, 2011. The decrease in the video annotated incidents was not statistically significant. This is likely due to the fact that the final number of video annotated critical events judged relevant for ACC+FCW was very small—crash relevant events and near crashes are truly rare events. A total of 5.5 MM was spent on video reviewing over 1000 potential conflicts selected based on different trigger criteria. From this dataset, only 21 events were judged to be actual crash relevant events, and hence retained for the analysis.
The effect of ACC+FCW on the number of FCW’s was also investigated using 2197 warnings in total. Figure 20 shows the number of warnings per 100km for baseline and treatment for different posted speeds. During baseline, warnings were logged but not displayed to the driver. Results show a reduction in the number of warnings in treatment, which suggests a positive effect of the bundle.

![Figure 20: Number of FCW warnings in baseline and treatment on motorways for different posted speeds (trucks).](image)

We also investigated hypothesized negative side effects of ACC+FCW in terms of increased secondary task engagement and attention to forward roadway. Given that ACC+FCW were expected to lower drivers' workload, secondary task engagement might increase. However, results showed no such effects. Overall, drivers kept their focus on the road while using ACC+FCW. This was true both during normal driving and during crash relevant events, though again, the analysis with incidents was based on a comparatively small number of events, and hence is to be viewed more as a trend.

Concerning braking response time during treatment, we observed no difference between driving with ACC+FCW and driving with FCW only. Nevertheless, the number of drivers who initiated a reaction before the warning was issued was significantly higher when only FCW was available. This effect is likely due to the fact that drivers rely on ACC to start braking.

Additionally, the risk matrix approach shows that when the system is activated positive effect between 44% and 16% is observed for the various conditions. This was the case for both slight and severe injuries. This is consistent with the effects on incidents and harsh breakings. The size of the effect is similar to the other indicators.

To make a prediction on an estimated benefit range for ACC+FCW, expert judgment was employed based on a combination of overall FOT results and previous knowledge of each VMC on the studied systems. The following procedure was adopted: as a low benefit boundary, the reduction observed in the video-based incident hypothesis (14%) was considered for all road types. Although this result was not statistically significant and only indicates a trend, we believe it is the best guideline we have for predicting the reduction of extremely risky cases, as it is the only indicator where the full driving context can be taken into account when reviewing event relevance, i.e. how close to a crash the situation really was. As upper bound, the reduction in kinematic incidents (36%) was adopted. This incident type addresses a broader range of situations where the level of risk involved is harder to assess, and thus points to a less conservative reduction. Since the risk decrease calculated with kinematic incidents was based on a limited amount of data and only six drivers, another
option would have been to use the reduction in harsh braking events instead (37%) as we did for cars, as it was based on seven times more data and 36 drivers. Multiplying this range (14 to 36%) by usage (42%), we arrive at 6 to 15%, which indicates the potential reduction in the target crash population (rear end crashes that occur within the operational scope of ACC+FCW, see chapter 6) if ACC+FCW was fully deployed. Table 10 summarizes the results.

Table 10: Estimated benefit of ACC+FCW (trucks).

<table>
<thead>
<tr>
<th>Road type</th>
<th>Usage</th>
<th>Estimated benefit range</th>
<th>Potential reduction in the target crash population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motorway</td>
<td>42%</td>
<td>14 - 36%</td>
<td>6 - 15%</td>
</tr>
</tbody>
</table>

It should be stated that it is impossible to consider more than a small part of the available information when performing this type of analysis, and it is possible that our selection has constrained our interpretation of the safety benefit in ways difficult to predict. Nevertheless, we believe the final dataset used was a good compromise between taking into account uncontrolled factors and being general at the same time. Moreover, the euroFOT dataset will be available for further in depth analysis that was not possible within the project timeline.

Conclusion in a nutshell

In summary, it can be said that the combination of ACC and FCW can have a positive effect on safety-related measures based on the data gathered in this FOT. This positive effect can be attributed to changes in the distance behaviour while driving with active ACC and FCW. Due to the predefined settings of the ACC time-headway the number of (intended or unintended) close approaching manoeuvres is highly reduced and prevents therefore critical driving situations. If in addition the driving situation exceeds the braking capacities of the ACC because of a highly decelerating vehicle in front the presented warnings (by the ACC and the FCW) give the driver appropriate time to react on the driving situation. In Annex 6, hypotheses results are presented individually.

4.1.8 LDW

In this sub-section we first offer an overview of the potential benefit of LDW, followed by the results of each individual hypothesis. Results come from the Swedish VMC (Volvo only).

Data selection

The analysis of LDW in trucks was done for all type of roads but limited to the operative range of the function, which means vehicle speeds above 60 km/h and visible lane markings. The intent was to limit the dataset to similar comparison situations, i.e. situations in which the function could have been used (baseline), and where it actually was used (treatment). No trends in function usage were found concerning road type, posted speed, or lane width. In fact, most trips had either LDW ON or OFF during the entire period. Therefore, no other filters were used as in the ACC+FCW case.

In the treatment data, portions of the data in which LDW was not active were filtered out in order to focus the analysis on LDW-related driver behaviour. This filtering might introduce a bias in the analysis, since it is the driver who selects when to use and not use LDW. In order to verify if the traffic environment in baseline and treatment was equalized enough, traffic density was used. Figure 21 shows that there are no major differences between density distributions in the two periods, what suggests that the selection bias was satisfactorily reduced.
Overview of the potential benefit

The LDW function was expected to support the driver in avoiding unintended lane departures, e.g. due to distraction. Overall, the function was expected to have a positive effect on both comfort and safety. The comfort side was mainly assessed subjectively with questionnaires in D6.3, while the safety benefits are addressed here.

In the overall results for LDW in trucks (Figure 22), indicators point toward a potential increase in safety when drivers use the function. Both Median Lateral Offset (i.e. vehicle distance from road edge) and the use of turn indicator during lane changes were increased, which suggests potentially improved lateral control.

The likelihood of experiencing a lateral crash relevant event also decreased when drivers used LDW. However, that decrease was not statistically significant, mainly because the number of annotated events in the end judged relevant for LDW was small. True crash relevant events and near crashes are rare. A total of 5.5MM was spent on video reviewing over 1000 potential conflicts selected based on kinematic conflict criteria. From this dataset, only 19 conflicts were judged to be actual relevant lateral conflict events, and hence retained for the analysis.

We also investigated possible negative side effects of LDW in terms of secondary task engagement and attention to forward roadway. Here, the data did not show any difference between baseline and treatment, i.e. drivers had similar focus on the forward roadway and did not engage more in secondary tasks when using LDW.

Unfortunately there is insufficient evidence to enable up-scaling of the safety impact of LDW+IW to EU-27 level. The difference in crash relevant events is not significant, and the two indicators that show a significant difference between baseline and treatment (Median Lateral Offset and Turn Indicator Usage) do not have a sufficiently strong connection to crash causation to suffice as a basis for up-scaling on their own.

It should be stated that it is impossible to consider more than a small part of the available information when performing this type of analysis, and it is possible that our selection has constrained our interpretation of the safety benefit in ways difficult to predict. Nevertheless, we believe the final dataset used was a good compromise between taking into account uncontrolled factors and being general at the same time. Moreover, the euroFOT dataset will be available for further in depth analysis that was not possible within the project timeline.
4.1.9 Risk Matrix Approach (RMA)

This section describes the safety impact on rear-end crashes between truck and passenger cars of equipping trucks with ACC+FCW, determined using the risk matrix approach. This risk matrix approach method is developed in euroFOT for the assessment of continuously operating functions, such as ACC and SRS. This risk matrix approach and the event based approach are complementary. The results below add a quantified view to the safety impact of ACC and FCW.

The risk matrix approach calculates the change in risk of drivers of passenger cars when equipping trucks with ACC+FCW. The approach does not take the risks for truck drivers into account. This is because there is not sufficient crash statistics to determine the injury and fatality risk on truck drivers (e.g. in truck to truck rear end crashes). This change in risk is called the Risk Modification Factor (RMF).

An RMF is calculated dividing the risk in treatment condition by the risk in baseline. A RMF below one suggests that safety was increased in treatment. The RMFs are calculated based on computer simulations of longitudinal vehicle conflicts. Monte Carlo simulations are performed to explore the risk in a wide spectrum of vehicle following situations. The risk is then assessed by mapping the observed car-following behaviour in the FOT to the simulated risks. The method is described in more detail in euroFOT deliverable 6.2 Analysis methods for user related aspects and impact assessment on traffic safety, traffic efficiency and environment.

As indicated in D6.2, specifically for the impact of ACC + FCW in trucks the model has been adapted based on GIDAS data, such that the impact speed is taken in mostly by the passenger car and hardly by the truck, rather that distributed evenly in case of two passenger cars. Delta V of the passenger car is 95% of the impact speed and delta V of the truck is 5%.

RMFs are calculated for different contextual situations, such as different road types, and for slight and severe injuries. The RMF could not be calculated for fatalities since the relation between impact speed and fatality is could not be empirically determined due to the limited number of fatal rear-end accidents in the crash databases.

The presented results compare the RMFs measured during baseline (driving without the ACC+FCW) with (1) having ACC+FCW: the whole treatment and (2) using ACC+FCW: treatment with ACC on only. Note that further filters (e.g., vehicle speed) as described in section 5.2.1 were not applied here. Note that this represents a quite different type of selection of baseline and treatment data than the one applied in section 5.2.1. Note also that...
the 5 seconds wait and see filter as described in section 5.2.1 was not applied here. Hence results might not be exactly comparable to those given in section 5.2.1.

FOT results

The effects of having ACC in trucks, as measured in the FOT, are shown in Table 11 and Figure 15 in terms of the Risk Modification Factor. The Risk Modification Factor is risk per km for the treatment divided by the risk per km for the baseline, so a risk modification factor below 1 suggests a potentially positive safety effect.

Also the mileage for baseline and treatment is presented. The results are provided separately for the different situations. A part of data could not be attributed to either one of the situations, and is reported under the category ‘unknown’.

<table>
<thead>
<tr>
<th>Situation</th>
<th>Risk Modification Factor</th>
<th>Mileage</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Slight</td>
<td>Severe</td>
<td>Distance travelled (km)</td>
<td>Fraction of total (%)</td>
<td>Distance travelled (km)</td>
</tr>
<tr>
<td>All situations</td>
<td>1.09</td>
<td>1.12</td>
<td>266261</td>
<td>100%</td>
<td>270030</td>
</tr>
<tr>
<td><strong>Road type</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motorway</td>
<td>1.12</td>
<td>1.14</td>
<td>211967</td>
<td>80%</td>
<td>206269</td>
</tr>
<tr>
<td>Rural</td>
<td>1.01</td>
<td>1.04</td>
<td>48833</td>
<td>18%</td>
<td>57355</td>
</tr>
<tr>
<td>Urban</td>
<td>0.96</td>
<td>0.94</td>
<td>4914</td>
<td>2%</td>
<td>5315</td>
</tr>
<tr>
<td>Unknown</td>
<td>1.29</td>
<td>1.82</td>
<td>546</td>
<td>0%</td>
<td>1091</td>
</tr>
<tr>
<td><strong>Motorway + traffic state</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Free flow</td>
<td>1.12</td>
<td>1.14</td>
<td>207134</td>
<td>78%</td>
<td>200958</td>
</tr>
<tr>
<td>Congestion</td>
<td>1.06</td>
<td>1.05</td>
<td>4826</td>
<td>2%</td>
<td>5299</td>
</tr>
<tr>
<td>Unknown</td>
<td>0.79</td>
<td>0.76</td>
<td>8</td>
<td>0%</td>
<td>11</td>
</tr>
<tr>
<td><strong>Lighting</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light</td>
<td>1.12</td>
<td>1.14</td>
<td>246585</td>
<td>93%</td>
<td>174205</td>
</tr>
<tr>
<td>Dark</td>
<td>1.11</td>
<td>1.11</td>
<td>18530</td>
<td>7%</td>
<td>94946</td>
</tr>
<tr>
<td>Unknown</td>
<td>1.04</td>
<td>1.06</td>
<td>1146</td>
<td>0%</td>
<td>878</td>
</tr>
</tbody>
</table>

The Risk Modification Factor for the all situations is not necessarily the weighted average of the Risk Modification Factors for the situations. Table 11 shows for instance that the RMF for severe injuries and for all situations is 1.12 while the RMFs for daylight and darkness are 1.14 and 1.11. The weighted average of these two is higher than 1.12. This is due to the shift in km driven in these conditions. Note that, as opposed to the RMF, the Risk Factor (RF) is a weighted average of the risk factors for specific situations. The RF is the risk per km for either baseline or treatment.

The Risk Modification factor is determined by four parameters obtained from the FOT data, being the speed of the FOT vehicle, the speed of the predecessor, the time headway and the acceleration of the FOT vehicle. The estimated negative safety effect is mainly due to closer time headways with ACC under certain conditions, mainly with low speeds. For the other parameters having ACC hardly shows any difference.
FOT results considering system activation

Risk modification factors for system state ACC ON are also calculated.

The effects of using ACC+FCW in the vehicle, as measured in the FOT, are shown in Table 12, and in Figure 24 in terms of the Risk Modification Factor. The Risk Modification Factor is risk per km for the treatment when ACC+FCW was being used, divided by the risk per km for the baseline, so a risk modification factor below 1 suggests a positive safety effect.

Also the mileage for baseline and treatment is presented. The results are provided separately for the different situations. A part of data could not be attributed to either one of the situations, and is reported under the category ‘unknown’.

These results suggest a positive safety effect when driving with ACC ON.

Table 12: Risk Modification Factor and mileage per situation for treatment ACC ON versus baseline.

<table>
<thead>
<tr>
<th>Situation</th>
<th>Risk Modification Factor</th>
<th>Mileage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Injuries</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slight</td>
<td>0.73</td>
<td>266261</td>
</tr>
<tr>
<td>Severe</td>
<td>0.75</td>
<td>100%</td>
</tr>
<tr>
<td>All situations</td>
<td>0.73</td>
<td>266261</td>
</tr>
</tbody>
</table>

Figure 23: Risk Modification Factor per situation treatment versus baseline.
### Road type

<table>
<thead>
<tr>
<th></th>
<th>RMF</th>
<th>LRMF</th>
<th>KM</th>
<th>IM</th>
<th>KM</th>
<th>IM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motorway</td>
<td>0.78</td>
<td>0.79</td>
<td>211967</td>
<td>80%</td>
<td>105482</td>
<td>86%</td>
</tr>
<tr>
<td>Rural</td>
<td>0.81</td>
<td>0.84</td>
<td>48833</td>
<td>18%</td>
<td>24606</td>
<td>20%</td>
</tr>
<tr>
<td>Urban</td>
<td>0.56</td>
<td>0.64</td>
<td>4914</td>
<td>2%</td>
<td>98</td>
<td>0%</td>
</tr>
<tr>
<td>Unknown</td>
<td>#N/A</td>
<td>#N/A</td>
<td>546</td>
<td>0%</td>
<td>-7889</td>
<td>-6%</td>
</tr>
</tbody>
</table>

### Motorway + traffic state

<table>
<thead>
<tr>
<th></th>
<th>RMF</th>
<th>LRMF</th>
<th>KM</th>
<th>IM</th>
<th>KM</th>
<th>IM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Free flow</td>
<td>0.78</td>
<td>0.79</td>
<td>207134</td>
<td>78%</td>
<td>105297</td>
<td>86%</td>
</tr>
<tr>
<td>Congestion</td>
<td>0.57</td>
<td>0.59</td>
<td>4826</td>
<td>2%</td>
<td>184</td>
<td>0%</td>
</tr>
<tr>
<td>Unknown</td>
<td>#N/A</td>
<td>#N/A</td>
<td>8</td>
<td>0%</td>
<td>1</td>
<td>0%</td>
</tr>
</tbody>
</table>

### Lighting

<table>
<thead>
<tr>
<th></th>
<th>RMF</th>
<th>LRMF</th>
<th>KM</th>
<th>IM</th>
<th>KM</th>
<th>IM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light</td>
<td>0.71</td>
<td>0.73</td>
<td>246585</td>
<td>93%</td>
<td>81338</td>
<td>67%</td>
</tr>
<tr>
<td>Dark</td>
<td>0.82</td>
<td>0.84</td>
<td>18530</td>
<td>7%</td>
<td>40792</td>
<td>33%</td>
</tr>
</tbody>
</table>

Figure 24: Risk Modification Factor per situation ACC ON versus baseline.

### Conclusion

The Risk Modification Factor for the FOT data was between 0.94 and 1.14 for both slight and severe injuries and for the different road types. In almost all conditions the calculated Risk Factor is higher for trucks equipped with ACC+FCW (Table 81). The apparent negative safety effect is mainly due to closer time headways in treatment. Nevertheless, when including system activation in the treatment definition (Table 12), the RMF varies between 0.84 and 0.56. The calculated Risk Factor is between around 16% and 44% less for the kilometres driven with ACC activated trucks. This suggests a potential increase in safety when ACC+FCW is being used.
5 Defining the target crash population

The first part of a safety benefit analysis involves defining the target crash population, i.e. the set of crashes (including the associated set of injuries and fatalities) that an evaluated function is potentially intended to, and potentially capable of, addressing. “Intended” is here to be understood as the purpose for which the original function developers have designed the function to address.

The latter is necessary to point out, because in addition to intended effects, there may also be unintended effects (positive or negative) when technologies are deployed. In euroFOT, the evaluation of unintended effects has been limited to the needed extend. Some key issues regarding potential negative impact were studied, e.g., whether drivers increase their secondary task engagement or decrease their level of attention towards the forward roadway when a function is in use. However, most of the analysis has focused on intended effects. Also, “capable of” is an important qualifier. All functions evaluated in euroFOT have certain operational constraints. For example, the evaluated ACC version does not operate at speeds below 30 kph, the evaluated FCW can only detect and warn for moving vehicles and the evaluated LDW and IW systems require visible lane markings and a minimum vehicle speed of 65 kph in order to function. If follows that crashes which occur outside these conditions cannot be addressed by the functions. Hence they cannot be part of the target crash population either, and thus need to be filtered out in the target crash population selection.

To provide the best possible fit with the empirical data collected in the FOT, the target crash population definition and the safety impact estimation are carried out in two steps. First, target crash populations and safety impacts are determined for the countries where the actual data collection has been taking place. This can be called estimation of the national or regional impact, depending on the number of countries involved. In a next step, the findings from the national/regional safety impact are used as a basis for projecting a wider EU-27 benefit. This two-step approach was chosen in order to introduce a certain degree of control for the variation in traffic environments that occurs across countries, and which hence defines the possibilities for any function to realise its intended effect.

Crash databases for the countries where each function has been evaluated were used to define the national/regional target crash populations. For Sweden the database used was STRADA. STRADA is a publicly available database that contains all police reported and most hospital reported traffic accidents that occur in Sweden. In this analysis, average crash population numbers for the years 2005 to 2008 were used. The full dataset included approximately 137 000 accidents.

For the UK, the database used was STATS19. STATS19 is also a publicly available database that provides information on all personal injury road accidents that occur on the public highway in Great Britain which are notified to the police within 30 days of occurrence, and in which one or more vehicles are involved and averages for the years 2005-2009 were used. The full 2005-2009 data set includes approximately 904 000 accidents.
For Germany, the German In-Depth Accident Study (GIDAS) database was used. GIDAS is not a national database in the same sense as STATS19 and STRADA. Rather it contains in-depth investigations of accidents in the Dresden and Hannover areas since 1999 and contains more than 20000 accident files. GIDAS provides a unique level of report data including full accident reconstructions, vehicle and injury data for each event and due to the way accidents are sampled, the dataset is assumed to be representative for the whole of Germany with regard to traffic accidents involving personal injuries. See Figure 25 for a comparison of the GIDAS dataset with German and European figures.

Figure 25: Comparison of casualty shares in road accidents by traffic participation and injury severity: EU-27, Germany, and GIDAS.

In euroFOT, the main advantage of using GIDAS data is that it allows for a detailed filtering out of crashes that are not relevant for the evaluated functions, based on data normally not found in national crash databases, such as crash and system boundary conditions. By filtering for pre-crash vehicle speed and other pre-crash constellations, the share of accidents which a system may be capable of addressing is more precisely estimated, at least compared to police reported national accident databases (see Figure 26).
5.1 ACC+FCW

For ACC+FCW, the target crash population consists of the set of rear end crashes that occur within the operational scope of ACC+FCW. This includes all crashes where two vehicles are travelling in the same lane and direction before the front of the following vehicle strikes the rear of the lead vehicle. Furthermore, since ACC only operates at speeds above 30 kph and FCW only detects target vehicles in motion, crashes where the lead vehicle is standing still or where the host vehicle speed is below 30 kph have to be excluded. Note that these last two filters are less precise than the first set of restrictions, since actual pre-crash vehicle speeds and movement are generally not well recorded in crash databases. A more detailed description of the queries made and the resulting numbers can be found in deliverable D6.2.

Official accidents statistics—and hence, the target populations generated for euroFOT—focus on injury accidents, but the safety mechanism indicates that there might be further benefits from addressing property-damage-only (PDO) accidents. How to use different data sources e.g., insurance databases to estimate what impact ACC+FCW might have on these accidents is addressed in D6.7 from the perspective of the insurance industry.

Different levels of detail in the available databases allowed a different level of selection filtering when it came to selecting relevant accidents where conditions are such that the system can be expected to work as intended. When integrating the applicable accident shares from different national databases to make a statement on EU-27 level, the shares from the national statistics were brought to the same level of selection filtering by applying rates from GIDAS, in order to compensate for those different levels of detail. In other words, inasmuch as the outcome is different between countries; it’s likely due to underlying differences in each country's accident population rather than an artifact from the data selection process.
ACC+FCW was evaluated for cars in Sweden and Germany. The crash target group’s share of all crashes in these two countries, and the base numbers for calculating them, are shown in Table 13.

Table 13: Average annual average accident frequencies and shares of the overall crash population for ACC+FCW relevant longitudinal crashes in Sweden and Germany, based on STRADA data collected 2005-2008 and GIDAS data collected 1999-2011.

<table>
<thead>
<tr>
<th>TARGET GROUP’S SHARE OF ALL CRASHES</th>
<th>SWEDEN (cars)</th>
<th>GERMANY (cars)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Motorway</td>
<td>Rural</td>
</tr>
<tr>
<td>Accidents</td>
<td>28.5%</td>
<td>8.3%</td>
</tr>
<tr>
<td>Fatalities</td>
<td>10.4%</td>
<td>1.1%</td>
</tr>
<tr>
<td>Injuries</td>
<td>43.0%</td>
<td>13.6%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TARGET GROUP</th>
<th>Accidents</th>
<th>Fatal</th>
<th>Severe</th>
<th>Slight</th>
</tr>
</thead>
<tbody>
<tr>
<td>SWEDEN (cars)</td>
<td>565.8</td>
<td>2.8</td>
<td>114.8</td>
<td>1221.8</td>
</tr>
<tr>
<td>GERMANY (cars)</td>
<td>8.3</td>
<td>0.4</td>
<td>3.5</td>
<td>8.8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ALL CRASHES</th>
<th>Accidents</th>
<th>Fatal</th>
<th>Severe</th>
<th>Slight</th>
</tr>
</thead>
<tbody>
<tr>
<td>SWEDEN (cars)</td>
<td>1983.8</td>
<td>26.5</td>
<td>355.0</td>
<td>2751.0</td>
</tr>
<tr>
<td>GERMANY (cars)</td>
<td>80.2</td>
<td>5.4</td>
<td>42.9</td>
<td>90.7</td>
</tr>
</tbody>
</table>

For trucks, ACC+FCW was evaluated in the UK and Germany. In Table 14 below, the size of the German and British target groups are shown.
Table 14: Accident target groups for ACC+FCW - relevant longitudinal crashes involving trucks in Germany and UK in terms of average annual accident frequencies and shares of the overall crash population.

<table>
<thead>
<tr>
<th>TARGET GROUP's SHARE IN ALL CRASHES</th>
<th>GIDAS (trucks)</th>
<th>UK (trucks)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Motorway Rural</td>
<td></td>
</tr>
<tr>
<td>Accidents</td>
<td>9.9% 0.3% 0.0%</td>
<td>24.8% 2.9% 0.9%</td>
</tr>
<tr>
<td>Fatalities</td>
<td>6.4% 0.3% 0.1%</td>
<td>7.4% 0.6% 0.0%</td>
</tr>
<tr>
<td>Injuries</td>
<td></td>
<td>5.3% 0.7% 0.2%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TARGET GROUP</th>
<th>GIDAS (trucks)</th>
<th>UK (trucks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accidents</td>
<td>. - . - . -</td>
<td>1818 1728 1078</td>
</tr>
<tr>
<td>Fatal</td>
<td>49 8 0</td>
<td>12 11 0</td>
</tr>
<tr>
<td>Severe</td>
<td>244 37 9</td>
<td>58 50 12</td>
</tr>
<tr>
<td>Slight</td>
<td>1553 277 345</td>
<td>552 515 309</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ALL CRASHES</th>
<th>GIDAS (trucks)</th>
<th>UK (trucks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accidents</td>
<td>. - . - . -</td>
<td>7320 59667 113817</td>
</tr>
<tr>
<td>Fatal</td>
<td>495 2721 1261</td>
<td>163 1710 943</td>
</tr>
<tr>
<td>Severe</td>
<td>4896 28054 37694</td>
<td>899 11703 14619</td>
</tr>
<tr>
<td>Slight</td>
<td>23384 85829 229190</td>
<td>10652 74566 130759</td>
</tr>
</tbody>
</table>

5.2 LDW+IW

For LDW+IW, the set of relevant crashes includes those which start with an unintentional lane departure, which are within the function’s operational scope (visible lane markers, vehicle speed above 65 kph), and which result in bodily injury.

In terms of selecting inadvertent lane departure initiated crashes, two possible accident scenarios exist. The first and most clear-cut is where a vehicle leaves the lane and crashes on its own without involvement of any other motor vehicle. The second is where the initial reason for the crash is an inadvertent lane departure, but where the resulting crash involves other vehicles.

Within these crash types it is notoriously difficult to further separate the portion of crashes relevant for Impairment Warning only (i.e. where drowsiness / long term distraction is the major contributing factor), as neither STRADA nor STATS19 records any such parameter.

Moreover, analysis of the euroFOT data suggests that in terms of function usage, LDW and IW overlap to approximately 97%. Based on this, the project decided to use the same target crash population for LDW and IW, i.e. to treat LDW+IW as an integrated system that addresses inadvertent lane departure in two separate but overlapping ways.

Furthermore, LDW cannot be expected to contribute significantly at intersections, as either appropriate lane markings are not available, or manoeuvres are performed at low speeds. Hence intersection related crashes were excluded. A more detailed description of the queries made and the resulting numbers can be found in deliverable D6.2.

---

1 The TRL study which includes ACC+FCW trucks relevant figures from GIDAS does not give accident numbers. See deliverable 6.7 for the approach taken to analyse German truck accident target groups.
LDW was evaluated in cars in Sweden and in trucks in the UK and the Netherlands (STATS19 was used for trucks in both locations). The annual rates for LDW+IW relevant crashes in these vehicle categories and countries are shown below in Table 15 and Table 16.

Table 15: Average annual accident frequencies for LDW+IW relevant to lane departure initiated crashes for Sweden, based on STRADA data collected in 2005-2008.

<table>
<thead>
<tr>
<th>TARGET GROUP's SHARE IN ALL CRASHES</th>
<th>LDW+IW cars</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Motorway</td>
<td>Rural</td>
</tr>
<tr>
<td>Accidents</td>
<td>26.0%</td>
<td>29.0%</td>
</tr>
<tr>
<td>Fatalities</td>
<td>47.2%</td>
<td>46.7%</td>
</tr>
<tr>
<td>Injuries</td>
<td>23.8%</td>
<td>28.4%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TARGET GROUP</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Accidents</td>
<td>516</td>
</tr>
<tr>
<td>Fatal</td>
<td>13</td>
</tr>
<tr>
<td>Severe</td>
<td>112</td>
</tr>
<tr>
<td>Slight</td>
<td>629</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ALL CRASHES</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Accidents</td>
<td>1984</td>
</tr>
<tr>
<td>Fatal</td>
<td>27</td>
</tr>
<tr>
<td>Severe</td>
<td>355</td>
</tr>
<tr>
<td>Slight</td>
<td>2751</td>
</tr>
</tbody>
</table>

Table 16: Average annual accident frequencies for LDW+IW relevant lane departure initiated crashes for UK, based on STATS19 data collected in 2005-2009.

<table>
<thead>
<tr>
<th>TARGET GROUP's SHARE IN ALL CRASHES</th>
<th>LDW trucks</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Motorway</td>
<td>Rural</td>
</tr>
<tr>
<td>Accidents</td>
<td>11.6%</td>
<td>0.6%</td>
</tr>
<tr>
<td>Fatalities</td>
<td>15.8%</td>
<td>4.2%</td>
</tr>
<tr>
<td>Injuries</td>
<td>10.4%</td>
<td>0.6%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TARGET GROUP</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Accidents</td>
<td>849</td>
</tr>
<tr>
<td>Fatal</td>
<td>26</td>
</tr>
<tr>
<td>Severe</td>
<td>105</td>
</tr>
<tr>
<td>Slight</td>
<td>1101</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ALL CRASHES</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Accidents</td>
<td>7320</td>
</tr>
<tr>
<td>Fatal</td>
<td>163</td>
</tr>
<tr>
<td>Severe</td>
<td>899</td>
</tr>
<tr>
<td>Slight</td>
<td>10652</td>
</tr>
</tbody>
</table>
5.3 Speed Limiter and Cruise Control (SL+CC)

When it comes to the parameter affected by Speed Limiter (SL) and Cruise Control (CC), i.e. vehicle speed, there is no empirical base available for estimating the importance of mean vehicle speed in FOT data in relation to crash involvement. The currently most well developed basis is the power model by (Nilsson, 1981, 2004) where a relation between mean speed on particular road segments and accident severity was inferred. However, it is difficult to apply this model to FOT data, since the empirical basis comes from cross-sectional data measured on selected road sections rather than from mean speeds as chosen by an individual driver across all possible driving conditions. The applicability of the model on FOT data therefore yet has to be validated (for further discussion, see (Cameron and Elvik, 2010)).

This means that it is difficult to define a group of target crashes for speed influencing systems. However, some very interesting work on the relationship between particular over speeding events and crash involvement has been performed by Taylor and colleagues (Taylor et al., 2000). These previous works could be used as the starting point in order to understand the influence of SL and CC on crash occurrence.

5.4 Blind Spot Information System (BLIS)

BLIS is evaluated at the Swedish VMC, and hence national target crash population selection has to be based on Swedish data. Here, to find lateral accidents relevant for BLIS, one has to identify crashes that are initiated when the driver initiates a lane change on a multilane road while unaware that a conflict vehicle is present in the adjacent lane.

Unfortunately, STRADA cannot distinguish between intended and unintended lane changes, and neither does it code for single vs multilane roads. Based on a deeper analysis of the way police code this type of crash, the best option was to query the database for crashes classified as related to overtaking manoeuvres. Unfortunately this is not very precise and is associated with large margins of error. In later up-scaling to an EU level, these numbers need to be weighed based on the relative proportion of time spent driving on multilane roads as compared to single lane roads.

Table 17: Average annual average accident frequencies for BLIS relevant crashes for Sweden, based on STRADA data collected in 2005-2008.

<table>
<thead>
<tr>
<th>BLIS</th>
<th>Motorway</th>
<th>Rural</th>
<th>Urban</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accidents</td>
<td>2.6%</td>
<td>0.5%</td>
<td>0.2%</td>
</tr>
<tr>
<td>Fatalities</td>
<td>0.0%</td>
<td>0.1%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Injuries</td>
<td>0.1%</td>
<td>0.5%</td>
<td>0.0%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TARGET GROUP</th>
<th>Motorway</th>
<th>Rural</th>
<th>Urban</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accidents</td>
<td>52</td>
<td>26</td>
<td>16</td>
</tr>
<tr>
<td>Fatal</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Severe</td>
<td>1</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>Slight</td>
<td>3</td>
<td>33</td>
<td>2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ALL CRASHES</th>
<th>Motorway</th>
<th>Rural</th>
<th>Urban</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accidents</td>
<td>1984</td>
<td>5589</td>
<td>7809</td>
</tr>
<tr>
<td>Fatal</td>
<td>27</td>
<td>241</td>
<td>70</td>
</tr>
<tr>
<td>Severe</td>
<td>355</td>
<td>1458</td>
<td>1213</td>
</tr>
<tr>
<td>Slight</td>
<td>2751</td>
<td>6790</td>
<td>9258</td>
</tr>
</tbody>
</table>
5.5 Navigation Systems

For navigation systems, it is difficult to identify a particular target crash population. The main function of a navigation system is to help drivers find their way towards their destination. Presumably, the information given is helpful at various route decision points such as intersections and exit/entrance ramps. One could therefore hypothesize that a certain portion of e.g., intersection accidents are related to the driver being overloaded with the task of identifying the right choice of route, and hence may either fail to manoeuvre his/her own vehicle properly, or fail to see or understand what other road users are doing and adapt to that.

However, finding a target crash population based on this hypothesis is not possible in the crash databases available, since they do not code for crash contributing factors on a sufficiently detailed level to extract this group from all crashes at intersections due to other reasons. Hence the hypothesis is not possible to verify in that data.

Looking at the empirical data, some safety related indicators did point to a significant positive change in treatment. However, to make a safety impact estimate, an important underlying assumption is that the systems behave similarly in different vehicles. In this data however there were large differences between the two tested navigations systems. It is therefore difficult to know for what system the positive effects would hold, i.e. which parts of the navigation function is it that drives these changes, and as described above, there is no support in the crash data for exploring this further.

Given the uncertainty in terms of by which mechanism navigation systems may influence safety, the difficulties in estimating the size of the target crash population (i.e. the group of accidents for which presence of a navigation system would have been an efficient countermeasure), and the inconsistencies in the changes between baseline and treatment, no specific target crash population can be given here, and no national impact can be predicted.
6 Impact on a national level

In this chapter, the safety impact (number of reduced accidents and injuries) will be calculated and presented on a national level using the benefit range derived from the empirical data (further presented in chapter 5). This means interpreting what the identified difference actually means in terms of how the target crash population can be expected to change if the function is widely deployed.

While many ways of doing this can be conceived, the following calculations are based on a rather simple formula. Essentially, the potential benefit range, i.e. the relative reduction in crashes and injuries one predicts would occur derived from the empirical data (see chapter 5) is multiplied by function usage rates and the size of the target crash population. Usage needs to be included, because if a system is in use, say, 20 % of the time and crash risk is randomly distributed over driving time, it can only actively contribute within that 20% of time. This would correspond to 1/5 of the target crash population.

National impact of ACC+FCW

To make the national impact assessment of ACC+FCW, we first need the usage and the potential predicted benefit range for ACC+FCW that comes out of the empirical analysis of the euroFOT data. These numbers are shown in Table 19 below.

<table>
<thead>
<tr>
<th>Table 18: Usage and predicted benefit range for ACC+FCW in cars.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>Usage</td>
</tr>
<tr>
<td>Predicted benefit range</td>
</tr>
</tbody>
</table>

When these numbers are applied to the target group’s shares of ACC+FCW relevant crashes for cars in Table 13, one gets the following results (Table 19):

<table>
<thead>
<tr>
<th>Table 19: The predicted safety impact of ACC+FCW for cars based on German and Swedish data.</th>
</tr>
</thead>
<tbody>
<tr>
<td>The percentages represent the proportion of the total crash population that ACC+FCW in cars might prevent, given 100% deployment in the vehicle fleet and assuming that the indicators tested in euroFOT do correlate with actual crashes.</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Sweden</td>
</tr>
<tr>
<td>Accidents</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Fatalities</td>
</tr>
<tr>
<td>Injuries</td>
</tr>
<tr>
<td>Germany</td>
</tr>
<tr>
<td>Accidents</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Fatalities</td>
</tr>
<tr>
<td>Injuries</td>
</tr>
</tbody>
</table>

The above table shows essentially that, according to the data, if ACC+FCW was deployed in the full car fleet, the potential benefit on e.g. motorways would be that car accidents on motorways could be decrease by 4.7-11.9 % in Sweden, and by 1.7-4.3 % in Germany.
To make a similar national impact assessment of ACC+FCW for trucks, we first need the usage and the potential predicted benefit range for ACC+FCW for trucks that comes out of the empirical analysis of the euroFOT data. These can be found in Table 20 below.

<table>
<thead>
<tr>
<th></th>
<th>Motorway</th>
<th>Rural</th>
<th>Urban</th>
</tr>
</thead>
<tbody>
<tr>
<td>Usage</td>
<td>42%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Predicted benefit range</td>
<td>14-36%</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

When these numbers are applied to shares of ACC+FCW relevant crashes for trucks presented in Table 14, one gets the following results (Table 21):

<table>
<thead>
<tr>
<th></th>
<th>Motorway</th>
<th>Urban</th>
<th>Rural</th>
</tr>
</thead>
<tbody>
<tr>
<td>UK</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accidents</td>
<td>1.5%</td>
<td>3.8%</td>
<td></td>
</tr>
<tr>
<td>Fatalities</td>
<td>0.4%</td>
<td>1.1%</td>
<td></td>
</tr>
<tr>
<td>Injuries</td>
<td>0.3%</td>
<td>0.8%</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Motorway</th>
<th>Urban</th>
<th>Rural</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germany</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accidents</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fatalities</td>
<td>0.6%</td>
<td>1.5%</td>
<td></td>
</tr>
<tr>
<td>Injuries</td>
<td>0.4%</td>
<td>1.0%</td>
<td></td>
</tr>
</tbody>
</table>

The above table shows essentially that, according to the data, if ACC+FCW was deployed in the full truck fleet, accidents could potentially be decreased by 1.5-3.8% in the UK, while in Germany, injured individuals involved in truck accidents on motorways could be potentially reduced by 0.4-1.0%.

**National impact of LDW+IW**

In terms of projecting a safety impact of LDW+IW, there are unfortunately insufficient results in the empirical data on which to base such an impact assessment. There was a trend towards fewer critical events per kilometre travelled when LDW+IW was in use, but this decrease was not statistically significant. Aside from that, there were two objective indicators that showed a significant difference between baseline and treatment (Mean Steering Wheel Angle and Turn Indicator Usage). Neither of these have a sufficiently strong connection to crash causation to suffice as a base for making a safety impact assessment, at least not on their own. For example, lane keeping is not necessarily something that drivers optimize, i.e. they may "bounce" between lane markers rather than try to stay exactly in the center of the lane all the time. This makes the coupling between the average Mean Steering Wheel Angle and the risk of a lane exceedance (and hence a crash) weak. Furthermore, the decrease is small, i.e. it's approximately a tenth of a degree, where the typical range on all road types for this PI is 4-5 degrees.

In short, based on the current empirical results, it is not possible to make a reliable safety impact estimate for LDW+IW, either nationally or on the EU-27 level.

---

2 The TRL study which includes ACC+FCW trucks relevant figures from GIDAS does not give accident numbers. See deliverable 6.7 for the approach taken to analyse German truck accident target groups.
National impact of BLIS

In terms of projecting a safety impact of BLIS, the story is unfortunately similar to LDW+IW, i.e. there are not enough results in the empirical data that can be used as basis for such an assessment. There was one objective indicator that showed a significant difference between baseline and treatment (Turn Indicator Usage). However, there is not a sufficiently strong connection between turn indicator usage and crash causation to warrant a safety impact assessment based solely on this indicator. Thus, based on the empirical results, it is not possible to make a safety impact estimate for BLIS, either nationally or on the EU-27 level.

National impact of SRS systems

SRS systems refer to two different systems with different purposes: SL is used to limit the vehicle speed on a voluntary basis, while CC is used to maintain a constant speed when driving conditions allow. Both SL and CC are mainly expected to have an effect on speed; therefore, models which attempt to quantify the relationship between instances of over speeding and accidents (Taylor et. al. 2000) were explored. The idea was to use these models as transfer functions when up scaling the potential benefit of SL and CC using speed-related indicators. However, we found that these models, which are based on measurements taken from select road locations rather than from continuous vehicle data, fail to capture several important aspects of the underlying safety mechanism. Among other things, they do not include traffic environment variables such as traffic density. Because of these limitations, a straightforward application of the models on the FOT data would lead to erratic results. For example, if a function mainly is used in low traffic densities—which is expected for CC—then an increase in average speed would not necessarily lead to an increase in average risk (which the models would predict), since risk is moderated also by traffic density.

Also, when it comes to over speeding events, the current dataset shows that the frequency of over speeding events goes down when drivers use SL (compared to baseline), but goes up when drivers use CC (compared to baseline). These opposite effects illustrate that drivers choose to use SL and CC under different traffic conditions, and also make it very difficult to interpret the effect of SRS as a whole.

Given these results and the limitations of the investigated models, our conclusion is that a trustworthy up scaling of SL/CC is not feasible; there are too many uncertainties for results of such an up scaling to be viewed as reliable. Different approaches for understanding the impact of SL/CC on accidents need to be further investigated in future work.

National impact of Navigation Systems

As stated earlier, the uncertainty in terms of which mechanisms associated to navigation systems may influence safety, result in difficulties in estimating the size of the target crash population. Furthermore due to the inconsistencies in the changes between baseline and treatment found in the empirical data, no specific target crash population has been defined, and hence no national impact can be predicted.

National impact of CSW and FEA

There were no predictions of national impacts for CSW and FEA. Regarding FEA, this function was not expected to have an influence on safety. Safety related hypotheses were therefore not tested for FEA. For CSW, only very limited testing was carried out and hence neither a full empirical analysis nor a national impact prediction was possible.
7 Up-scaling of euroFOT safety impacts to EU-27

To determine potential benefits on EU-27 level, the FOT results need to be linked with an applicable European accident target population. Hence, up-scaling estimates what share of accidents across Europe could be affected if the reductions of near-crash events and kinematic incidents were an indicator of road safety improvement. Safety impact assessment with national accident data for EU-27 countries means up-scaling from the surrogate safety measures identified in the FOT to an EU-27 wide accident population.

EU-27 accident target groups

The main difference between national and European level safety impacts is the target population. For up-scaling to EU-27 level, the target group estimation is based on European accident data. This is then amended by detailed accident characteristics from national accident databases which are not available in pan-European databases such as CARE, Eurostat, or IRTAD.

The most straightforward way to estimate the accident target group for EU27 is to assume that the assessments made at a National level apply at the EU27 level, i.e. that the benefit range and usage rates derived from the euroFOT data apply to all vehicles in EU-27 in the same way as they do to the vehicles used in the euroFOT project. These would then be applied to EU27 accident statistics. Note that the above assumption may not be valid, i.e. there may be differences in traffic environments and general driver behaviour that invalidates this approach. However, while awaiting further research on this topic, the simplistic approach proposed here will be pursued.

All parameters are available per road type that can be linked to European sub-target groups per road type. The following data sources were used to get to the estimations:

- EUROSTATS & CARE: Pan-European data available for each country such as number of fatal car occupants, accidents and casualties divided by location and overall injury accident figures by national definition and reporting.
- STRADA, STATS19, DESTATIS: Accidents available further divided by collision type, by impact direction and characteristics of accident site (posted speed limit, weather, time).
- GIDAS: In-depth data on accident kinematics (pre-crash behaviours, collision speeds & decelerations, sequential manoeuvres) to filter for stationary vehicles and system relevant boundaries.

Hence, the results of the national target group estimations are brought to same level of accident filtering and integrated to average shares per road type (see D6.7). The differences between countries (e.g. high share of motorway traffic Germany vs. mostly rural traffic in Eastern Europe) are taken into account by identifying the number of involved car occupants per road type for each country. Table 22 shows the number of fatalities on European level clustered into road types and the number of fatally injured car occupants based on these European databases (Road Accident Statistics 2011, UN-ECE) for the year 2008, which is the latest year for which data is available from all EU-27 countries.

The approach for truck accidents is slightly different, since the target population also includes casualties other than car occupants and the filtering by accident type (involved collision opponents) is more complex. An approach from a recent TRL study that addressed a similar issue (TRL 2010) was taken into account.

In fact, combining different data sources might lead to further bias, since e.g. we implicitly assume that driving (and having an accident) on a motorway in Germany is comparable to driving or accidents on a motorway in countries where there are general speed limits. All limitations, factors and assumptions – also regarding the fact what applying incident reductions on accident data means - are summarised below.
Table 22: Road fatalities in EU-27: Car occupants & distribution over road type.

<table>
<thead>
<tr>
<th>UNECE Transport Division, 2008</th>
<th>Fatally injured car occupants</th>
<th>All road fatalities (EU-27, 2008)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Motorways</td>
<td>Rural</td>
</tr>
<tr>
<td>Austria</td>
<td>367</td>
<td>71</td>
</tr>
<tr>
<td>Belgium</td>
<td>479</td>
<td>139</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>622</td>
<td>38</td>
</tr>
<tr>
<td>Cyprus</td>
<td>26</td>
<td>8</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>573</td>
<td>30</td>
</tr>
<tr>
<td>Denmark</td>
<td>196</td>
<td>31</td>
</tr>
<tr>
<td>Estonia</td>
<td>69</td>
<td>91</td>
</tr>
<tr>
<td>Finland</td>
<td>202</td>
<td>9</td>
</tr>
<tr>
<td>France</td>
<td>2,205</td>
<td>233</td>
</tr>
<tr>
<td>Germany</td>
<td>2,368</td>
<td>495</td>
</tr>
<tr>
<td>Greece</td>
<td>708</td>
<td>120</td>
</tr>
<tr>
<td>Hungary</td>
<td>448</td>
<td>54</td>
</tr>
<tr>
<td>Ireland</td>
<td>160</td>
<td>2</td>
</tr>
<tr>
<td>Italy</td>
<td>2,116</td>
<td>452</td>
</tr>
<tr>
<td>Latvia</td>
<td>167</td>
<td></td>
</tr>
<tr>
<td>Lithuania</td>
<td>237</td>
<td>24</td>
</tr>
<tr>
<td>Luxembourg</td>
<td>20</td>
<td>6</td>
</tr>
<tr>
<td>Malta</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Netherlands</td>
<td>299</td>
<td>86</td>
</tr>
<tr>
<td>Poland</td>
<td>2,540</td>
<td>35</td>
</tr>
<tr>
<td>Portugal</td>
<td>358</td>
<td>96</td>
</tr>
<tr>
<td>Romania</td>
<td>1,323</td>
<td>21</td>
</tr>
<tr>
<td>Slovakia</td>
<td>292</td>
<td>14</td>
</tr>
<tr>
<td>Slovenia</td>
<td>82</td>
<td>13</td>
</tr>
<tr>
<td>Spain</td>
<td>1,516</td>
<td>109</td>
</tr>
<tr>
<td>Sweden</td>
<td>234</td>
<td>18</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>1,312</td>
<td>160</td>
</tr>
<tr>
<td><strong>18,923</strong></td>
<td><strong>2,264</strong></td>
<td><strong>20,762</strong></td>
</tr>
</tbody>
</table>

Accident data for injured car occupants and injury accidents is available in a similar format (see D6.7, Annex). Due to different severity definitions and quality of police reporting systems, they are not as comparable between countries as the numbers of road fatalities are across Europe (IRTAD underreporting report).

Underreporting is taken into account in deliverable 6.7. For the purpose of the safety impact assessment the EU-27 safety impacts are calculated by using the injury numbers as reported in Road Accident Statistics 2011.

Table 23 shows in summary the accident numbers from EU-27 countries that are considered to be the best estimations for car occupants to link safety impacts of car systems based on F.O.T results to the European accident scenario.
Table 23: All road fatalities and injury accidents and involved car occupants in 2008 (own calculations based on CARE, EUROSTATS, IRTAD and UN-ECE RAS 2011).

EU-27 - Summary of Road Accidents & Casualties (2008)

<table>
<thead>
<tr>
<th></th>
<th>Motorway</th>
<th>Rural</th>
<th>Urban</th>
<th>all</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fat. inj. car occupants</td>
<td>1,571</td>
<td>13,678</td>
<td>3,673</td>
<td>18,922</td>
</tr>
<tr>
<td>Injured car occupants</td>
<td>79,952</td>
<td>364,875</td>
<td>468,470</td>
<td>913,297</td>
</tr>
<tr>
<td>Injury accidents</td>
<td>60,682</td>
<td>324,876</td>
<td>847,152</td>
<td>1,232,710</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Motorway</th>
<th>Rural</th>
<th>Urban</th>
<th>all</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road fatalities</td>
<td>2,264</td>
<td>20,762</td>
<td>14,890</td>
<td>37,916</td>
</tr>
<tr>
<td>Injured road users</td>
<td>90,678</td>
<td>453,299</td>
<td>1,058,366</td>
<td>1,602,344</td>
</tr>
<tr>
<td>Injury accidents</td>
<td>60,682</td>
<td>324,876</td>
<td>847,152</td>
<td>1,232,710</td>
</tr>
</tbody>
</table>

EU-27 safety impacts of ACC+FCW

In order to provide input for further assessment of the function on EU-27 level in WP6500, the safety impacts of ACC+FCW cars and ACC+FCW trucks are provided, under the assumption that all vehicles were equipped in terms of:

- Reduction of addressed injury accidents in EU-27.
- Reduction of addressed road fatalities and injured road user in EU-27

The following factors would need to be taken into account to enable a full assessment of the true benefits but are not covered by the applied filtering and modeling of target groups and are not therefore considered with this approach.

- There was no effectiveness of the functions observed or proven in euroFOT in terms of the system leading to any avoidance of accidents or injuries. Further research with the euroF.O.T data should lead to insights on how systems improve driving in the addressed situations. Until that link is made, the general assumption that an incident reduction can be linked to a conservatively filtered accident population is the best estimate to determine what the effect of a system could be.
- When a function addresses an accident scenario in which it is designed to be active, it remains subject to further advanced modeling or simulation whether injury avoidance or mitigation effects can be derived in that accident target group.
- The relevant shares of involved individuals and accidents were estimated based on national data from a limited set of countries, which may not necessarily reflect the real accident situation in the other EU countries (see deliverable D6.7).
- Usage ratios and changes of safety-related indicators had to be assumed to be the same for all EU-27 countries according to the data available on FOT level. Human behaviour with the system and driver capabilities might vary strongly between these countries (see concern regarding effectiveness).
- Usage of the system as it is intended to assist the driver is not necessarily reflected by the usage rate in terms of kilometers driven with the system on. On European level, customer needs might show different usage/user behaviour with the functions. This can also be subject to changes or behavioural adaptation or learning over time.

Due to their current technological development stage the **car functions** included in euroF.O.T are not capable of (and not intended to) address any accidents involving vulnerable road users. This means the traffic participants that are in the scope of the system’s function are restricted to the car occupants themselves. Accident data related to traffic participation (car occupants) is available for all European countries (see Figure 27).
For ACC+FCW, that includes both occupants of leading and following cars in addressable rear-end accidents. Therefore, the EU accident target group is given in terms of shares of involved injured car occupants and accidents in which cars were involved according to the identified accident mechanism.

For **truck functions** in euroFOT, the target group is not limited to occupants of heavy goods vehicles, but includes a rather large share of car occupants that are involved in accidents caused by trucks. On EU level, information on occupant level is not available that would allow to determine accident target groups separated by pairing of involved vehicle types. This need to be estimated based on available national information. In a similar approach, the TRL impact assessment of AEBS (2010) determined a share of addressable accidents in which N3 category vehicles (heavy goods larger than 12 tonnes) were the guilty party, a front-to-rear shunt occurred and no stationary lead vehicles were involved. This matches with the objective of identifying accidents relevant for ACC+FCW in trucks. In euroFOT, the resulting shares were compared with the national target groups from STATS19 and STRADA. Despite not using the same filtering procedure on European data, an overlap between car and truck system shares is avoided due to the fact that both accident data analysis approaches consider the respective guilty party – and this can only be one truck or one car (see deliverable D6.7).

![Figure 27: Qualitative illustration of filter process of relevant accidents and casualties for euroFOT safety impacts – Note: sizes do not reflect actual shares of target groups.](image)

Under the various assumptions that FOT safety surrogate measures may be used to estimate actual accident reductions, the following results for ACC+FCW cars were determined as up scaled EU-27 target groups. Due to the fact that no accident or injury reduction was observed in euroFOT and due to the integration issues of data sources, these potential benefits were determined based on non-crash indicators and could in reality deviate from these estimations significantly.

**EU-27 results for ACC+FCW cars:** The shares of the ACC+FCW target groups on national accident data provided the basis for determining the shares to be used as target group from European data.
Table 24: EU-27 target population in terms of relevant accidents/casualties for ACC+FCW cars.

<table>
<thead>
<tr>
<th>EU-27 target group</th>
<th>Motorway (%)</th>
<th>Rural (%)</th>
<th>Urban (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatally inj. car occ.</td>
<td>10.28%</td>
<td>0.90%</td>
<td>1.62%</td>
</tr>
<tr>
<td>Injured car occ.</td>
<td>15.55%</td>
<td>5.26%</td>
<td>5.89%</td>
</tr>
<tr>
<td>all fatalities</td>
<td>7.13%</td>
<td>0.60%</td>
<td>0.40%</td>
</tr>
<tr>
<td>all injured</td>
<td>13.71%</td>
<td>4.23%</td>
<td>2.61%</td>
</tr>
<tr>
<td>all injury accidents</td>
<td>13.74%</td>
<td>4.69%</td>
<td>2.23%</td>
</tr>
</tbody>
</table>

In chapter 5 of the present deliverable, it is described how the results from hypothesis testing on safety-related indicators on FOT level were used to interpret a generic safety impact. Table 25 shows the resulting range per road type as well as the usage.

Table 25: ACC+FCW cars - results from impact assessment of safety-related hypothesis per road type.

<table>
<thead>
<tr>
<th></th>
<th>Motorway (%)</th>
<th>Rural (%)</th>
<th>Urban (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACC Usage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>lower bound impact</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>upper bound impact</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Similar to the calculations in chapter 4 (national safety impacts), the integrated EU estimations in terms of ACC+FCW relevant shares of accidents and casualty are linked with the range derived from FOT level results during the safety impact assessment, taking into account the usage as observed in the FOT. Table 26 shows the results of the EU-27 safety impact estimations if all vehicles were equipped.

Table 26: The estimated safety impact of ACC+FCW for passenger cars based on EU-27 accident data

<table>
<thead>
<tr>
<th>EU-27 target group</th>
<th>Motorway (%)</th>
<th>Rural (%)</th>
<th>Urban (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatally inj. car occ.</td>
<td>low</td>
<td>high</td>
<td>low</td>
</tr>
<tr>
<td></td>
<td>1.68%</td>
<td>4.30%</td>
<td>0.09%</td>
</tr>
<tr>
<td>Injured car occ</td>
<td>low</td>
<td>high</td>
<td>low</td>
</tr>
<tr>
<td></td>
<td>2.54%</td>
<td>6.50%</td>
<td>0.52%</td>
</tr>
<tr>
<td>Fatalities (all)</td>
<td>low</td>
<td>high</td>
<td>low</td>
</tr>
<tr>
<td></td>
<td>1.16%</td>
<td>2.98%</td>
<td>0.06%</td>
</tr>
<tr>
<td>Injuries (all)</td>
<td>low</td>
<td>high</td>
<td>low</td>
</tr>
<tr>
<td></td>
<td>2.24%</td>
<td>5.73%</td>
<td>0.42%</td>
</tr>
<tr>
<td>Injury accidents (all)</td>
<td>low</td>
<td>high</td>
<td>low</td>
</tr>
<tr>
<td></td>
<td>2.24%</td>
<td>5.75%</td>
<td>0.47%</td>
</tr>
</tbody>
</table>

For ACC+FCW trucks, the impact assessment leading to EU-27 figures is carried out according to the analysis of car systems. The relevant share in line with the national target groups is taken from the TRL study on AEBS addressing rear-end accidents without stationary targets (see D6.7 for details). Note that different to the ACC+FCW cars target group, the trucks systems addresses accidents in which N3 category vehicles (heavy truck) were the guilty party and collided with the rear-end of another two track vehicle. Hence, potential casualties in host vehicle and lead vehicle are coded under different types of accident involvement in accident statistics, while for similar car systems, both sub-groups mostly consisted of car occupants. Hence, the shares in Table 27 can only be given as the share on all accidents and casualties per road type.
Table 27: Generic share on EU-27 accidents/casualties relevant for ACC+FCW trucks.

<table>
<thead>
<tr>
<th>ACC+FCW trucks (% on all fat./inj./acc.)</th>
<th>Motorway</th>
<th>Rural</th>
<th>Urban</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatalities</td>
<td>5.61%</td>
<td>0.55%</td>
<td>-</td>
</tr>
<tr>
<td>Injured</td>
<td>2.99%</td>
<td>0.55%</td>
<td>-</td>
</tr>
<tr>
<td>Acc. Inj.</td>
<td>3.65%</td>
<td>0.52%</td>
<td>-</td>
</tr>
</tbody>
</table>

For the effects of truck functions, the ACC+FCW up-scaling is done solely for motorways. In real-world as in euroFOT, these vehicles are used on motorways most of the time. Therefore, the overall benefit potential is the same as the potential on motorways (Table 28).

Table 28: ACC+FCW trucks - results from impact assessment of safety-related hypothesis per road type.

<table>
<thead>
<tr>
<th></th>
<th>Motorway</th>
<th>Rural</th>
<th>Urban</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACC Usage</td>
<td>42%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>lower bound impact</td>
<td>-14%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>upper bound impact</td>
<td>-36%</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Similar to chapter 4 (national safety impacts), the integrated EU estimations in terms of ACC+FCW relevant shares of accidents and casualty are linked with the range derived from FOT level results during the safety impact assessment taking into account the usage as observed in the FOT. Table 29 shows the results of the EU-27 safety impact estimations if all vehicles were equipped.

Table 29: The estimated safety impact of ACC+FCW for trucks based on EU-27 accident data

<table>
<thead>
<tr>
<th></th>
<th>Motorway</th>
<th>EU-27 target group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>low</td>
<td>high</td>
</tr>
<tr>
<td>Fatalities (all)</td>
<td>0.33%</td>
<td>0.85%</td>
</tr>
<tr>
<td>Injuries (all)</td>
<td>0.18%</td>
<td>0.45%</td>
</tr>
<tr>
<td>Injury accidents (all)</td>
<td>0.21%</td>
<td>0.55%</td>
</tr>
</tbody>
</table>

The shares of all previous results tables (Table 26, Table 29) are considering the different impact and usage values per road type and give the relevant shares in terms of reduction per road type for each accident data indicator. Table 30 now provides the relevant numbers in relation to all accident or casualties as an overview for ACC+FCW for both cars and trucks.

Table 30: Overview of estimated safety impacts of ACC+FCW based on EU-27 accident data

<table>
<thead>
<tr>
<th>EU-27 (total/ all roads)</th>
<th>ACC+FCW cars</th>
<th>ACC+FCW trucks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>low</td>
<td>high</td>
</tr>
<tr>
<td>Fatalities</td>
<td>0.11%</td>
<td>0.23%</td>
</tr>
<tr>
<td>Injuries</td>
<td>0.35%</td>
<td>0.59%</td>
</tr>
<tr>
<td>Injury accidents</td>
<td>0.33%</td>
<td>0.55%</td>
</tr>
</tbody>
</table>
In D6.7, these results for ACC+FCW cars and ACC+FCW trucks serve as input for further calculations of the socioeconomic impact assessment that is carried out according to FESTA. The final results of this assessment are documented in deliverable D6.7.
8 Discussion and conclusion

euroFOT was the first European large-scale Field Operational Test (FOT). An FOT is a study undertaken to evaluate a function, or functions, under normal operating conditions in environments typically encountered by the host vehicle(s) using quasi-experimental methods. In euroFOT, we evaluated a number of traffic effects of Advanced Driver Assistance Systems (ADAS) that are already available in the market or are mature enough to be tested as commercial functions.

This deliverable (D6.4) presents the final impact of studied functions on traffic safety. In general terms, impact assessment is comprised of a set of logical steps which help to quantify the potential consequences that the studied function may have. The final step in such an assessment is to estimate the extent to which the functions being evaluated in euroFOT can be expected to alter the current crash population on EU-27 level (accidents, injuries, and fatalities). This last step was only possible to carry out for ACC+FCW. For the other functions, inherent limitations in the generalization of the empirical results and in our understanding of the functions’ influence on real-world crash causation mechanisms prevented us from making a prediction on the whole EU-27 level. Or put the other way; having access to significant empirical results from different test sites and a relatively well-established insight into the addressed crash causation mechanisms, in the way we had for ACC+FCW, seems to be a minimum requirement for a full EU-27 impact analysis.

The limitations in empirical result generalizations and knowledge on crash causation mechanisms are listed individually in chapters 5 and 10. These are strongly recommended to be taken into account in future FOT’s. However, it also needs to be pointed out that despite the lack of full EU-27 results for some of the functions, euroFOT did provide a large body of knowledge on how these functions affect a number of safety related indicators and thus did provide an improvement to the overall picture of how they work in the real-world.

Our analysis of ACC+FCW showed that, as previously hypothesized, the benefit mainly comes from a safety margin improvement, i.e. drivers drive with increased time headway when using ACC+FCW. One important reason for this increase is the time-headway settings available in ACC. These can never be lower than the legally prescribed or recommended values, which are a limit that is not always respected in baseline driving. It is not farfetched to couple this increase in time headway to the other observed positive effects, such as the reduction in the frequency of harsh braking events or incidents when using the function. In principle, when drivers have more time to respond in a safe manner, the need for sudden and strong reactions is decreased.

We also investigated potential negative side effects of ACC+FCW in terms of increased secondary task engagement, attention to forward roadway, and drowsiness. Essentially, the use of ACC+FCW was expected to lower driver workload which may have detrimental effects on the driver’s attention to the primary driving task. However and interestingly, while car drivers during non-critical situations (i.e. normal driving) were three times more likely to engage in visual secondary tasks when using ACC+FCW (e.g., reading maps, looking at passengers or objects in the car), this difference did not show up during critical situations. These results imply that drivers keep their focus to the road when they need to do so. In addition, ACC+FCW presence does not seem to affect the amount of drowsy driving undertaken. For trucks, no particular side effects on driver behaviour were observed for the function.

To highlight potential benefit of ACC+FCW on a wider scope, the observed improvements in what can be called the safety-related measures (e.g., reduction of kinematic and subjective events) were linked to overall accident statistics. Note that the use of the safety-related measures for this up-scaling is a natural consequence of the lack of actual crashes in the
empirical data, which means no empirical change in crash frequency was observed. Hence, safety impacts were estimated under the assumption that a reduction based on the above measures can be applied to relevant real-world accident data. Given this assumption, the crash population can potentially change if all vehicles were equipped with ACC+FCW according to Table 9. Further estimations based on the addressable rear-end target crash population were also made, e.g., regarding involved injured individuals.

Table 31: Summary of the impact of ACC+FCW, based on the assumption that the selected safety-related measures are good indicators of how the accident population would change if all vehicles were equipped with ACC+FCW

<table>
<thead>
<tr>
<th>Vehicle type</th>
<th>Road type</th>
<th>Usage (portion of the total driving in treatment)</th>
<th>Changes between baseline and treatment in safety related measures in the FOT data. Positive numbers indicate an estimated decrease in risk when ACC+FCW is in use.</th>
<th>Potential reduction in the target crash population (rear end crashes)</th>
<th>Potential reduction in the injury accident population per road type in EU-27</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger Cars</td>
<td>Motorway</td>
<td>51%</td>
<td>32 - 82%</td>
<td>16 - 42%</td>
<td>2.2 - 5.8%</td>
</tr>
<tr>
<td>Passenger Cars</td>
<td>Rural</td>
<td>31%</td>
<td>32 - 45%</td>
<td>10 - 14%</td>
<td>0.47 - 0.65%</td>
</tr>
<tr>
<td>Passenger Cars</td>
<td>Urban</td>
<td>19%</td>
<td>32%</td>
<td>6%</td>
<td>0.14%</td>
</tr>
<tr>
<td>Trucks</td>
<td>Motorway</td>
<td>42%</td>
<td>14 - 36%</td>
<td>6 - 15%</td>
<td>0.2 - 0.6%</td>
</tr>
</tbody>
</table>

A computer simulation approach, called the Risk Matrix approach, was also developed to estimate changes in risk for longitudinal safety conflicts when using ACC+FCW. The simulations explored a wider range of baseline and treatment data selections than the empirical hypothesis testing. For data selection comparable to that in the empirical hypothesis testing, mixed results were obtained for cars while for trucks, the simulations indicated a general risk decrease in treatment.

The ability to combine information from different sites in Europe was a key component in either reinforcing or questioning individual test site results. We believe this strengthens the final conclusions for ACC+FCW. Although creating a very heavy burden of harmonization work, in future FOT’s, multi-site data collection must be carefully considered, since the benefits are tremendous.

We also observed a positive impact of LDW (+IW in cars), but to a smaller extent, compared to ACC+FCW. When using the function, both car and truck drivers showed better lateral vehicle control. There was also a reduction in the frequency of video-review based incidents, but this should be viewed as a trend, since results were not statistically significant. As hypothesized in the beginning of the project, LDW(+IW) increased the use of turn indicators; though not as much as expected (only 3% in trucks and 10% in cars). In addition, results suggest that LDW(+IW) does not negatively affect drivers during critical situations in terms of engagement in secondary tasks and attention to the forward roadway, despite the finding that use of the function in cars is associated with a significant increase in secondary task engagement—more specifically, use of nomadic devices such as mobile phones — during normal driving.
Despite the overall LDW(+IW) impact being positive, there are not enough solid results to base a EU-27 up-scaling of the function on. Since the difference in crash relevant events is not significant, there are only two indicators that show a significant safety improvement between baseline and treatment (lateral control and turn indicator usage). Neither of these have a sufficiently strong or clear connection to the crash causation mechanisms underlying lane departure initiated crashes to suffice as a base for up-scaling in their own right.

For the **Speed Regulation System** (SL+CC), it has been shown that when SL is active the likelihood of observing an over-speeding event is divided by 2 and the likelihood of observing an hard braking event by 1.5, but very small or insignificant effects are found for other events (strong jerk or critical time gap). The CC effect on over-speeding is opposite showing a strong increase, while strong jerk, critical time gap, and hard braking occurrences are divided by 3 (which is not surprising given that CC is mainly used under free flow conditions). These findings highlight the relationships between systems usage and driving conditions, showing that level of traffic is likely to be an important parameter. There are sufficient indices to hypothesize the following:

- **SL** is used on all speed limits, but mainly when the likelihood of being caught by a speed enforcement camera is high (road with low speed limits or low congestion level). Other factors that can influence drivers’ choice to use SL may include environmental concerns, money saving, compliance with limits, sensation seeker, etc.
- **CC** is used in high speed roads under free flow conditions that allow to cruise at the prevailing speed limit without deteriorating safety too much (drivers use the system when it is possible to speed).

Given these results and the limitations of the investigated models, our conclusion is that a trustworthy up scaling of SL/CC is not feasible; there are too many uncertainties for results of such an up scaling to be viewed as reliable. Different approaches for understanding the impact of SL/CC on accidents need to be further investigated in future work.

For the **navigation system**, it was observed that on urban roads driving is safer if the system is activated. The positive effect on driving safety is rather global. It is reflected in positive changes in lane keeping behaviour, distance to the lead vehicle and hard braking events. Since safety benefits of navigation systems are not reported in the literature and also because no experiment is known what investigates possible mechanisms through which a navigation system might support driving safety. It is very difficult to judge whether and under which assumptions the measured effects can be generalized. If the analyses are conducted separately for familiar and unfamiliar journeys, it turns out that the positive effects on driving safely are mainly based on familiar routes. This result contradicts all naïve assumptions one might have on why navigation systems might be able to improve driving safety. Because the safety mechanism for the navigation systems is not known, it is not clear which type of accidents are prevented; therefore, the potential safety benefit caused by navigation systems needs further investigation. Therefore, it is necessary to first explore potential safety benefits of navigation systems in experimental settings in order to understand in more detail how and why navigation systems affect driving behaviour in urban areas and how these changes are linked to driving safely. As soon as the safety mechanism on how navigation systems improve driving safety is understood, up-scaling of the FOT results to a higher level will become possible. In case of the navigation system, the analyses conducted in euroFOT hint at a potential safety benefit of a system that up to now has not been considered as a system that positively impacts driving safety.

The safety indicators studied for **BLIS** showed no difference between baseline and treatment with the exception of turn indicator usage, which decreased by approximately 10% when BLIS was in use. This result does not have a sufficiently strong or clear connection to the
crash causation mechanisms underlying lane departure initiated crashes to suffice as a base for up-scaling in its own right.

For **FEA**, since no effect on safety was hypothesized, no results are available. For **CSW**, based on the specific experimental design for the CSW (no baseline phase) an assessment of the safety benefit is not possible. The analysis of the CSW was mainly focused on the impact on driver related aspects based on subjective data.

A number of factors need to be considered when putting results into perspective. Firstly, the fact that truck fleets, that voluntarily agreed to join the project, were safety-oriented from the beginning might have affected the analysis outcome. As drivers in this context can be expected to have an initially high level of safety in their driving, especially those who have received coaching concerning safe behaviours, the expected impact of making various safety systems available to them is comparatively low. A similar argument can be made for the car drivers in Sweden. As they were white collar Volvo Car employees, they represent only a very small share of the driver population who might have different driving habits concerning, for example, the tendency to use certain functions.

Secondly, while hypothesis results come from testing on actual empirical FOT data (CAN signals, video footage, GPS) the up-scaling section was based on the assumption that the selected benefit range for ACC+FCW can be directly applied to the target crash population. However, this assumption is questionable, since the true relationship between the investigated safety indicators and actual crash involvement is largely unknown. This is also the reason why a range was adopted rather than a single value.

Data selection in baseline and treatment played a big role in the analysis of, especially ACC+FCW. Due to low usage, data in which ACC was OFF were removed from treatment. This introduced a bias in the analysis (driver selection bias) which was satisfactorily reduced by the introduction of data filters aimed at equalizing traffic conditions in both periods. Further research should be directed at the inclusion of new filters (e.g., traffic density), so that ACC OFF does not need to be artificially excluded. Also, new comparison situations, such as CC ON x ACC ON, need to be investigated.

In addition, it is important to point out that studied functions also have an effect on, for example, comfort, as shown in deliverable 6.3; therefore, different dimensions should be analyzed together for a complete benefit picture. Such an overall analysis is done in deliverable 11.3 Final Report. In addition, user-related aspects, traffic efficiency and environment results are available in other euroFOT deliverables.

In summary, during the safety impact analysis in euroFOT we were able to test the most relevant hypotheses determined by researchers in universities, research centres, and OEM’s. Results, which are of different nature, coming from different data sources and sites across Europe, offer an invaluable insight into functions and how drivers use them in the real-world. Since the project timeframe was limited, not all of the interesting research questions could be addressed; however, euroFOT data will be available for further investigation, and results presented in this deliverable shall serve as guidelines for future studies.

Further research may be directed at a joint analysis of objective and subjective data, which were collected using questionnaires and during focus group discussions. More insight could be gained as well by investigating the differences among individual drivers concerning, for example, safe behaviour or preferences. In addition, the difference between cars and trucks is an interesting topic that should be further investigated.
9 Lessons learned and future recommendations

The euroFOT project was very ambitious in many aspects and all of the partners learned a lot from that experience. Some of them (if not all of them) were involved for the first time in such a large scale naturalistic driving study, and many problems were encountered and solved for the first time. In order to help future FOT’s in reaching a successful safety impact analysis, some lessons learned have been identified and detailed by partners involved in euroFOT. Here is a list of the main topics, divided into General and Function-specific.

General

- There is a need for further development of a methodology suitable for functions used on a voluntary basis. For such functions, it is not relevant to use the classical approaches like speed-accidents relationships which merge all driving conditions in a single formula. Considering function activation and filtering the data in order to focus the analysis to those conditions in which the function being studied was used the most helped us to cope with this issue.

- For a function used on a voluntary basis, the data collection needs to be long enough to capture rare situations (using the function under a specific but rare driving condition). For example, with 500,000 km collected at the French FOT, some of the more complex hypotheses were answered using less than 1% of the data. For functions used on a driver's demand there is a higher risk that some factor combinations will not present within the data. Having enough exposure and preferably a similar amount in baseline and treatment ensures a balanced analysis. An additional reason for a long enough data collection is to find comparable driving situations in baseline and treatment. Finding comparable situation various situational variables have to be considered. The consideration of additional situational variables shrinks the amount of available data.

- The setup of the FOT should ideally be able to account for influences from seasonal effects. For example: A found decrease in speed between baseline driving that was mainly done in summer and treatment driving that was mainly done in winter might be highly depending on the seasonal weather conditions. One way to do this is by using a control group.

- Different experimental setups (only CAN data collection, CAN+video data collection, only questionnaires) prevent a good comparability among different test sites.

- Having video footage of the FOT helped to better understand and to validate a number of algorithms developed during the project (e.g., traffic state and incident trigger). Video footage made it possible to evaluate such things as attention to forward roadway on engagement in secondary tasks, which are very important indicators of driver attention.

- Selecting drivers that drive very often the same trips (e.g., to work and back) might increase data that does not includes various different situational variables but instead a lot of trips that are highly comparable to each other and give therefore precise/reliable results when comparing baseline and treatment. In general, data that well suited for comparison between baseline and treatment could be assessed by using algorithms to identify same trips based on GPS data.

- Without the use of video systems a reliable detection of the driver is complicated and might lead to effects that result from different vehicle users (e.g. family members).
The familiarity of the driver with the system should be considered when selecting the drivers.

The definition of road types should be detailed enough to consider differences within rural and urban roads. Especially within urban roads there might be big differences in driving conditions when considering small one-lane roads as the same type of road as bigger two-lane urban bypasses (where driving is more comparable to motorways). To overcome this problem detailed and reliable map information is needed.

Harmonisation between different test sites widens the amount of situational variables (resp. data for these situational variables) that can be considered in the analysis. It gives additionally indication whether the results from one test site is reliable. The level of harmonisation should be as low as possible meaning ideally on a collected data level so that the data are put together and one analysis is done afterwards with the complete data set.

Baseline and treatment periods should be equally filtered in order to focus the analysis on those conditions in which the function being studied was used the most (typical usage scenario in the dataset). Usage within these conditions must be taken into account before making the decision whether or not to consider function activation (e.g. where ACC is actively controlling the longitudinal vehicle movement) as a filtering criterion. This data selection step should be done as soon as possible prior to the start of any analysis or data annotation.

Enough time should be reserved for video annotation of incidents. Annotating events ranked by a certain severity measure (e.g., deceleration) from top to bottom helped us saving time while keeping those events that were more likely to be “true” incidents.

Using automatic incident detection based on kinematic pattern (as applied in Ger1 VMC) is able to save time for event recognition but needs sufficient time for algorithms validation in a pre-test to avoid missing events or high false detection rates.

Pilot phase should be long enough to test the experimental setup. Especially the tool chain and the monitoring for data collection transfer and storage should be tested extensively to avoid problem during the FOT that cause missing data.

Incident detection is a crucial task that needs further research and validated algorithms to be used as an efficient safety indicator.

Analysis using both database and file system was beneficial, since different approaches offer different advantages. The database turned out to be extremely good for quick checks on overall trends and averages. The file system was better for more complex calculations (e.g., complex filtering), especially those made on-the-fly.

Considering different functions as bundles rather than trying to isolate individual effects is necessary when more than one function is addressing the same crash type. Principally, without a clear and detailed understanding of the underlying crash causation mechanism(s), it is not possible to distinguish individual function effects when they address the same crash type.

Traffic state estimation is a crucial task when studying longitudinal but not automated systems because drivers tends to use such systems when they feel confident about safety.

Reliable traffic volume estimation is not yet possible using single front radar information and future FOT’s should develop methods to better estimate the level of congestion.
• The intrinsic correlation between different trips of a same driver needs to be taken into account in the analyses, especially if the number of participants is not large enough.

• Data sharing among different test sites should be discussed at the beginning to have reliable information on what can be shared and what is confidential information.

• It should be guaranteed that no function is available within the baseline phase.

• To extend information on situational variables information from external database sources can/should be considered (e.g. weather or traffic state information).

• To be able to upscale the results from FOT-data to a higher level, it is necessary to assume that the changes detected between conditions in the FOT are caused by the function. This requires that the function and its impact on driving are already widely studied in the literature based on experimental approaches. For other, less investigated functions up-scaling is extremely difficult because the mechanisms behind the detected changes are not understood well enough.

• Considering several safety indicators proved useful because it helped to estimate whether there is a more global effect on safety or whether the effect is specific for one special indicator. This helps to judge whether the system effects are reliable but makes up-scaling difficult.

• For some functions only a rough estimation of their impact on driving safety (in the sense of more vs. less safe) makes sense. Putting that change into exact numbers might be closer to guessing than to scientific calculations.

• Data extracted from periods when the function was inactive during treatment must be handled with care. A direct comparison to baseline, for example, is not proper, since in baseline both periods when drivers would and would have not used the function are present.

Function-specific

1. The SRS system is very different from highly automated or advanced systems that are embedded in high-end vehicles, in the sense that the principle is basic and does not rely on any automatic device.

2. Navigation systems do not only influence driving on the stabilisation level but also on higher levels (e.g. route choice). This makes a causal interpretation of the measured effects of the function difficult because a variety of different mechanism but also moderating factors might cause the effects. This makes the estimation of potential safety benefits more complex than for functions that have a well describable impact on driving on mainly the stabilisation level (e.g. ACC).

3. The way functions are used (because of either driver preference or, sometimes, HMI restrictions) might help to explain certain effects in the data. For example, LDW was either ON or OFF during the whole period in most trips. This prevented us from further filtering the data to those situations in which LDW was used the most, because no preferences could be observed.

4. ACC disengages as soon as the driver hits the brake pedal; therefore, in order to find harsh braking events during ACC ON conditions, a few seconds after ACC disengagement must still be considered as within the function active zone (five seconds in euroFOT).
References


Benmimoun, M. et al. (2011). Incident detection based on vehicle CAN-data within the large scale field operational test "euroFOT", 22nd Enhanced Safety of Vehicles Conference (ESV 2011), Washington, DC/USA.


Hautzinger et al., Epidemiological cohort study on accident risk and user acceptance of heavy goods vehicles equipped with ESC, ACC and LDW, Scientific evaluation of vehicle, accident and driving data collected for BGL/BG Verkehr/KRAVAG project “SICHER. FÜR DICH. FÜR MICH.”, www.fahrer-assistenz-systeme.de, 2012, Hamburg (Germany).


Robinson, B.J., Hulshof, W., Robinson, T., Knight, I., 2010. AEBS and LDWS exemptions study: final report. Transportation Research Laboratory.


Annex 1: Hypotheses results for cars: ACC+FCW

Hypothesis: ACC decreases the number of critical time-headway to the leading vehicle

Comparison situations
- **Baseline**: All baseline with ACC state off
- **Treatment**: All treatment with ACC state active (plus 5 sec after ACC shut off)

Filtering criteria
- Travelled time with vehicle speed not null > 5 min.
- Vehicle speed >=50 km/h
- THW>0 (car following)
- Expected speed >60 km/h
- Minimum mileage for each driver in baseline/treatment conditions (100km)

Factors
- Road type
- Weather (only motorway)
- Lighting (only motorway)

Performance indicators (PIs)
- Number of Time-headway under 0.5s per 100km
- Percentage of Time-headway under 0.5s

Data
All drivers (N), which have sufficient number of accumulated kilometres (>100 km) in Baseline and Treatment, were used for the analyses. N=174 for motorway (709607 km), N=64 for rural (37211 km) and urban (33728 km) roads, N=80 for lighting conditions (557663 km) and N=77 for weather conditions (555412 km). Lighting and weather conditions were only analyzed for motorways.

Statistical Methods
- Wilcoxon signed-rank test and 2 sample T-test.
Results: Number of Time-headway under 0.5s per 100km

Figure 28: Number of Time-headway under 0.5s per 100km.

Table 32: Summary of results.

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Baseline Mean</th>
<th>Treatment Mean</th>
<th>% Increase/Reduction</th>
<th>N</th>
<th>Mileage [km]</th>
</tr>
</thead>
<tbody>
<tr>
<td>motorway</td>
<td>22.22</td>
<td>6.02</td>
<td>-72.86</td>
<td>174</td>
<td>709607</td>
</tr>
<tr>
<td>rural</td>
<td>8.9</td>
<td>1.6</td>
<td>-82.02</td>
<td>64</td>
<td>37211</td>
</tr>
<tr>
<td>urban</td>
<td>13.3</td>
<td>4.9</td>
<td>-63.16</td>
<td>64</td>
<td>33728</td>
</tr>
<tr>
<td>good</td>
<td>25.66</td>
<td>7.07</td>
<td>-72.58</td>
<td>77</td>
<td>489399</td>
</tr>
<tr>
<td>adverse</td>
<td>18.32</td>
<td>4.63</td>
<td>-74.95</td>
<td>77</td>
<td>66013</td>
</tr>
<tr>
<td>day light</td>
<td>27.86</td>
<td>7.75</td>
<td>-72.47</td>
<td>80</td>
<td>413223</td>
</tr>
<tr>
<td>dark</td>
<td>15.51</td>
<td>4.7</td>
<td>-69.5</td>
<td>80</td>
<td>144440</td>
</tr>
</tbody>
</table>
Results: Percentage of Time-headway under 0.5s.

Figure 29: Percentage of Time-headway under 0.5s.

Table 33: Summary of results.

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Baseline Mean</th>
<th>Treatment Mean</th>
<th>% Increase/Reduction</th>
<th>N</th>
<th>Mileage [km]</th>
</tr>
</thead>
<tbody>
<tr>
<td>motorway</td>
<td>2.16</td>
<td>0.41</td>
<td>-80.65</td>
<td>110</td>
<td>651099</td>
</tr>
<tr>
<td>rural</td>
<td>Not statistically significant</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>urban</td>
<td>Not statistically significant</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>good</td>
<td>2.82</td>
<td>0.57</td>
<td>-79.27</td>
<td>77</td>
<td>489399</td>
</tr>
<tr>
<td>adverse</td>
<td>1.48</td>
<td>0.25</td>
<td>-83.06</td>
<td>77</td>
<td>66013</td>
</tr>
<tr>
<td>day light</td>
<td>1.48</td>
<td>0.32</td>
<td>-78.35</td>
<td>80</td>
<td>413223</td>
</tr>
<tr>
<td>dark</td>
<td>3.01</td>
<td>0.63</td>
<td>-77.4</td>
<td>80</td>
<td>144440</td>
</tr>
</tbody>
</table>

Conclusions

The number of critical time gaps (THW<0.5 sec) to the leading vehicle was reduced by 72.86% in the evaluation on motorway driving and are therefore lower than the decrease on rural roads (82.02%) but higher than on urban roads (63.16%). The results within the different weather and lighting conditions vary between 69.5% and 74.95%. As expected the frequency of critical time gaps is the highest on motorways compared to other road types. The lower frequency in adverse weather conditions (compared to good weather conditions) can be explained by a more conservative driving style in these conditions. The almost halved frequency in the darkness (compared to daylight) may be attributed to a lower traffic density.

Analyzing the percentage of THW under 0.5 seconds no statistically significant results could be found on rural and urban roads. The assessment on motorways
shows a reduction of 80.65% which is also reflected in the number of the different weather and lighting conditions (between 77.4% and 83.06%) which were also analyzed on motorways.
Hypothesis: ACC reduces the average speed

Comparison situations

- Baseline: All baseline with ACC state off
- **Treatment**: All treatment with ACC state active

Filtering criteria

- Travelled time with vehicle speed not null > 5 min.
- Vehicle speed >=50 km/h
- THW>0 (car following)
- Expected speed >60 km/h
- Minimum mileage for each driver in baseline/treatment conditions (100km)

Factors

- Road type
- Weather (only motorway)
- Lighting (only motorway)

Performance indicators (PIs)

- Average speed

Data

All drivers (N), which have sufficient number of accumulated kilometres (>100 km) in Baseline and Treatment, were used for the analyses. N=174 for motorway (709607 km), N=64 for rural (37211 km) and urban roads (33728 km), N=80 for lighting conditions (557663 km) and N=77 for weather conditions (555412 km). Lighting and weather conditions were only analyzed for motorways.

Statistical Methods

Repeated measures ANOVA.
Results

Figure 30: Average speeds in baseline and treatment.

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Baseline</th>
<th>Treatment</th>
<th>% Increase/Reduction</th>
<th>N</th>
<th>Mileage [km]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Mean</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>motorway</td>
<td>116.7</td>
<td>119.02</td>
<td>1.99</td>
<td>174</td>
<td>709607</td>
</tr>
<tr>
<td>rural</td>
<td>79.7</td>
<td>83.3</td>
<td>4.52</td>
<td>64</td>
<td>37211</td>
</tr>
<tr>
<td>urban</td>
<td>70*</td>
<td>71.5*</td>
<td>2.14</td>
<td>64</td>
<td>33728</td>
</tr>
<tr>
<td>good</td>
<td>118.02</td>
<td>119.63</td>
<td>1.46</td>
<td>77</td>
<td>489399</td>
</tr>
<tr>
<td>adverse</td>
<td>112.22</td>
<td>117.4</td>
<td>4.99</td>
<td>77</td>
<td>66013</td>
</tr>
<tr>
<td>day light</td>
<td>115.11</td>
<td>115.85</td>
<td>0.65</td>
<td>80</td>
<td>413223</td>
</tr>
<tr>
<td>dark</td>
<td>117.15</td>
<td>118.38</td>
<td>1.05</td>
<td>80</td>
<td>144440</td>
</tr>
</tbody>
</table>

* only where expected speed >60 km/h

Conclusions

The average speed increased by 1.99% when driving with ACC+FCW active on motorways. Additionally, an increase of 2.14% on urban roads and 4.52% on rural roads was found. The increases in different lighting conditions are 0.65% in day light conditions and 1.05% in the dark. The difference between good and adverse weather conditions is higher (1.46% in good weather conditions and 4.99% in adverse weather conditions) but might be influenced by the low mileage in adverse weather conditions. Comparisons between conditions (e.g., average speed in dark and day light) should be made with care, since traffic density might considerably differ.
Hypothesis: ACC reduces the number of incidents

Comparison situations

- Baseline: All baseline with ACC state off
- Treatment: All treatment with ACC state active (plus 5 sec after ACC shut off)

Filtering criteria

- Travelled time with vehicle speed not null > 5 min
- Vehicle speed >=50 km/h
- THW>0 (car following)
- Expected speed >60 km/h
- Minimum mileage for each driver in baseline/treatment conditions (100km)

Factors

- Weather (only motorway)
- Lighting (only motorway)

Performance indicators (PIs)

- Number of incidents per 100 driven km based on vehicle kinematics
- Number of incidents per 100 driven km based on video annotation

Data

All drivers (N), which have sufficient number of accumulated kilometres (>100 km) in Baseline and Treatment, were used for the analyses.

- Number of incidents based on vehicle kinematics: N=110 for motorway (651099 km), N=80 (557663 km) for lighting conditions and N=77 (555412 km) for weather conditions. Lighting and weather conditions were only analyzed for motorways.
- Number of incidents based on subjective video analysis: N=92 (60471km) independent of the road type.

Statistical Methods

Wilcoxon signed-rank test and 2 sample T-test.
Results: Number of incidents based on vehicle kinematics per 100km.

![Figure 31: Number of incidents based on vehicle kinematics per 100km (passenger cars).](image)

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Baseline Mean</th>
<th>Treatment Mean</th>
<th>% Increase/Reduction</th>
<th>N</th>
<th>Mileage [km]</th>
</tr>
</thead>
<tbody>
<tr>
<td>motorway</td>
<td>0.76</td>
<td>0.14</td>
<td>-81.9</td>
<td>110</td>
<td>651099</td>
</tr>
<tr>
<td>rural</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>urban</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>good</td>
<td>0.74</td>
<td>0.18</td>
<td>-75.13</td>
<td>77</td>
<td>489399</td>
</tr>
<tr>
<td>adverse</td>
<td>0.41</td>
<td>0.07</td>
<td>-82.33</td>
<td>77</td>
<td>66013</td>
</tr>
<tr>
<td>day light</td>
<td>0.59</td>
<td>0.11</td>
<td>-81.54</td>
<td>80</td>
<td>413223</td>
</tr>
<tr>
<td>dark</td>
<td>0.56</td>
<td>0.16</td>
<td>-71.6</td>
<td>80</td>
<td>144440</td>
</tr>
</tbody>
</table>
Results: Number of incidents based on video annotation per 100km (not significant)

![Graph showing number of incidents per 100km](image)

**Figure 32: Number of incidents based on video annotation per 100km (passenger cars).**

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Baseline Relative risk (events/100km)</th>
<th>Treatment Relative risk (events/100km)</th>
<th>% Increase/Reduction</th>
<th>N</th>
<th>Mileage [km]</th>
</tr>
</thead>
<tbody>
<tr>
<td>overall</td>
<td>0.027</td>
<td>0.019</td>
<td>-31.75</td>
<td>92</td>
<td>60471</td>
</tr>
</tbody>
</table>

**Table 36: Summary of results.**

Conclusions

The number of incidents based on kinematics was reduced by 81.9% within the assessment on motorways. For the weather and lighting conditions the reduction varies between 71.6% and 82.33%.

In treatment the number of incidents based on video annotation was reduced by 31.75%. Results were not statistically significant, so they indicate a trend.

The lack of significance is likely due to the fact that the final number of video annotated critical events judged relevant for ACC+FCW was very small.
Hypothesis: ACC reduces the number of hard braking events

Comparison situations

- **Baseline**: All baseline with ACC state off
- **Treatment**: All treatment with ACC state active (plus 5 sec after ACC shut off)

Filtering criteria

- Travelled time with vehicle speed not null > 5 min
- Vehicle speed >= 50 km/h
- THW>0 (car following)
- Expected speed >60 km/h
- Minimum mileage for each driver in baseline/treatment conditions (100km)

Factors

- Road type
- Weather (only motorway)
- Lighting (only motorway)

Performance indicators (PIs)

- Number of high decelerations per 100 driven km
- Number of strong braking reactions

Data

All drivers (N), which have sufficient number of accumulated kilometres (>100 km) in Baseline and Treatment, were used for the analyses.

- Number of high decelerations per 100 driven km: N=110 for motorway (651099 km), N=80 (557663 km) for lighting conditions and N=77 (555412 km) for weather conditions. Lighting and weather conditions were only analyzed for motorways.
- Number of strong braking reactions: N=64 for motorway (58508 km), rural (37211 km) and urban roads (33728 km).

Statistical Methods

Wilcoxon signed-rank test and 2 sample T-test.
Results: Number of high decelerations per 100 driven km

Figure 33: Number of high decelerations per 100 driven km (passenger cars).

Table 37: Summary of results.

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Baseline</th>
<th>Treatment</th>
<th>% Increase/Reduction</th>
<th>N</th>
<th>Mileage [km]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Mean</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>motorway</td>
<td>0.23</td>
<td>0.07</td>
<td>-69.23</td>
<td>110</td>
<td>651099</td>
</tr>
<tr>
<td>rural</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>urban</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>good</td>
<td>0.25</td>
<td>0.09</td>
<td>-65.78</td>
<td>77</td>
<td>489399</td>
</tr>
<tr>
<td>adverse</td>
<td>0.15</td>
<td>0.02</td>
<td>-84.6</td>
<td>77</td>
<td>66013</td>
</tr>
<tr>
<td>day light</td>
<td>0.33</td>
<td>0.11</td>
<td>-67.02</td>
<td>80</td>
<td>413223</td>
</tr>
<tr>
<td>dark</td>
<td>0.21</td>
<td>0.07</td>
<td>-65.29</td>
<td>80</td>
<td>144440</td>
</tr>
</tbody>
</table>
Results: Relative risk of strong braking reactions

Figure 34: Relative risk of strong braking reactions (passenger cars).

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Baseline Relative risk</th>
<th>Treatment Relative risk</th>
<th>% Increase/Reduction</th>
<th>N</th>
<th>Mileage [km]</th>
</tr>
</thead>
<tbody>
<tr>
<td>motorway</td>
<td>1</td>
<td>0.59</td>
<td>-40.81</td>
<td>64</td>
<td>58832</td>
</tr>
<tr>
<td>rural</td>
<td>1</td>
<td>0.55</td>
<td>-45.12</td>
<td>64</td>
<td>37728</td>
</tr>
<tr>
<td>urban</td>
<td>Not statistically significant</td>
<td></td>
<td></td>
<td>64</td>
<td>34436</td>
</tr>
<tr>
<td>good</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>adverse</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>day light</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>dark</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Conclusions

The number of high decelerations was reduced by 69.23% within the assessment on motorways. For the weather and lighting conditions the reduction varies between 65.29% and 67.02% with an outlier for adverse weather and 84.6%.

In treatment the strong braking reactions on motorways were reduced by 40.81% compared to Baseline. On rural roads the reduction is 45.12%. No significant results were found on urban roads.

Combining the two PI's using mileage as a weight, the overall reduction on motorways was 67%.
Hypothesis: ACC increases the average THW

Comparison situations
- **Baseline**: All baseline with ACC state off
- **Treatment**: All treatment with ACC state active

Filtering criteria
- Travelled time with vehicle speed not null > 5 min
- Vehicle speed >=50 km/h
- THW>0
- Expected speed >60 km/h
- Minimum mileage for each driver in baseline/treatment conditions (100km)

Factors
- Road type
- Weather (only motorway)
- Lighting (only motorway)

Performance indicators (PIs)
Average time headway (THW)

Data
All drivers (N), which have sufficient number of accumulated kilometres (>100 km) in Baseline and Treatment, were used for the analyses. N=174 for motorway (709607 km), N=64 for rural (37211 km) and urban roads (33728 km), N=80 for lighting conditions (557663 km) and N=77 for weather conditions (555412 km). Lighting and weather conditions were only analyzed for motorways.

Statistical Methods
Repeated measures ANOVA
Results

Table 39: Summary of results.

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Baseline</th>
<th>Treatment</th>
<th>% Increase/Reduction</th>
<th>N</th>
<th>Mileage [km]</th>
</tr>
</thead>
<tbody>
<tr>
<td>motorway</td>
<td>Mean</td>
<td>Mean</td>
<td>16.21</td>
<td>173</td>
<td>709607</td>
</tr>
<tr>
<td>rural</td>
<td>3.51</td>
<td>4.08</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>urban</td>
<td>Not statistically significant</td>
<td>2.82</td>
<td>15.1</td>
<td>64</td>
<td>33728</td>
</tr>
<tr>
<td>good</td>
<td>3.57</td>
<td>4.18</td>
<td>17.27</td>
<td>77</td>
<td>489399</td>
</tr>
<tr>
<td>adverse</td>
<td>3.66</td>
<td>4.19</td>
<td>14.55</td>
<td>77</td>
<td>66013</td>
</tr>
<tr>
<td>day light</td>
<td>3.45</td>
<td>3.97</td>
<td>15.03</td>
<td>80</td>
<td>413223</td>
</tr>
<tr>
<td>dark</td>
<td>4.38</td>
<td>4.92</td>
<td>12.36</td>
<td>80</td>
<td>144440</td>
</tr>
</tbody>
</table>

Conclusions

The average THW increases by 16.21% on motorways and 15.1% on urban roads. On rural roads no significant changes could be found. Within the analyses of weather and lighting conditions the results vary between 12.36% and 17.27%.
Hypothesis: The frequency of drowsy driving will increase when using ACC+ FCW

Comparison situations

- Baseline: All baselines with vehicle speed above 60km/h and THW are not null and expected speed > 60 km/h and Impairment Warning (IW) available.
- Treatment: All treatments with vehicle speed above 60km/h and THW are not null and expected speed > 60 km/h and IW warning available and ACC\(^3\) On.

Filtering criteria

See Comparison situations.

Factors

None

Performance indicators (PIs)

Warnings issued by IW (IW detects drowsiness reliably; hence the frequency of warnings issued can be used to assess the frequency of instances of driver drowsiness).

Chunking

None

Data

The total time duration of the trips where an Impairment Warning was issued compared to the total time duration of the trips where no Impairment warning was issued, in Baseline and Treatment respectively.

Statistical Methods

Calculation of Risk Ratio with 95% confidence interval.

<table>
<thead>
<tr>
<th></th>
<th>Sum of trip durations where a warning was issued</th>
<th>Sum of trip durations where no warning was issued</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>97</td>
<td>1285</td>
</tr>
<tr>
<td>Treatment</td>
<td>40</td>
<td>515</td>
</tr>
</tbody>
</table>

\(^{3}\) FCW is always available when ACC is on, hence the conclusions hold for ACC+FCW
Results

Risk Ratio = 1.03 CI [0.72, 1.46]  
Not significant.

Consequently there is no difference in frequency of drowsiness driving when using ACC+FCW.

Conclusions

There is not enough evidence to say that vehicles equipped with ACC+FCW will increase the frequency of drowsy driving.
Hypothesis: The driver changes the use of ACC over time by increasing occurrence of overriding the ACC system by using the accelerator pedal

Comparison situations

All trips in the treatment period were labeled either “before” or “after” in such a way that for each driver

- Any trip labeled “after” was done later than any trip labeled “before”.
- The total duration of the trips labeled “before” is (approximately) equal to the total duration of the trips labeled “after”.

We then compared the usage of accelerator pedal given ACC is active “before” (Baseline) and “after” (Treatment).

Filtering criteria

None

Factors

- Road type: both any and motorway
- Weather: both any and rain

Performance indicators (PIs)

Percentage of time the accelerator pedal is used given ACC is active.

Chunking

None

Data

Trips were required to be at least 5 min long and to have speed = 0 less than 20% of the time. Drivers who did not use ACC during Baseline or Treatment, or whose usage was to a large extent unbalanced were excluded. The data was paired according to driver ID. Data from a total of 58 drivers were used.

Statistical Methods

We did extensive exploratory data analysis using the Matlab toolbox which we have developed exclusively to address this and similar hypotheses. We then performed a paired (according to driver ID) t-test in order to see whether the difference in ACC usage between Baseline (“before”) and Treatment (“after”) is statistically significant. The analysis was done separately for all possible choices of factor levels.
Results

We observed that the usage of accelerator pedal when the ACC is active increased from 6.2% to 7.1% (road type: any) and from 6.7% to 7.3% (road type: motorway). Results are summarized in Table 41.

Table 41: Significant results: accelerator pedal usage (passenger cars).

<table>
<thead>
<tr>
<th>Factors</th>
<th>Response variables</th>
<th>Baseline (&quot;before&quot;)</th>
<th>Treatment (&quot;after&quot;)</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road: any</td>
<td>Accel. pedal usage: 6.2%</td>
<td>6454</td>
<td>6876</td>
<td>0.9% increase.</td>
</tr>
<tr>
<td>Weather: any</td>
<td>Number of trips: 5 969</td>
<td>ACC active (h): 4 924</td>
<td>p-value: 0.039</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Accel. pedal usage: 6.7%</td>
<td>2 923</td>
<td>2 345</td>
<td>0.6% increase.</td>
</tr>
<tr>
<td>Road: motorway</td>
<td>ACC active (h): 2 923</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weather: any</td>
<td>ACC active (h): 2 345</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 36: Accelerator pedal usage (given ACC is active) change per driver. The red dots represent different drivers.

Conclusions

We observed an increase in usage of accelerator pedal when overriding the state of ACC. The drivers pushed the accelerator pedal on average 6.6% of time ACC was active.
Hypothesis: Using ACC+FCW, drivers’ reaction time (time to reach the brake pedal) will increase if ACC is used most of the time and decrease if only the FCW function is actually used.

Comparison situations
- Baseline: All baselines with vehicle speed above 50km/h and THW not null and expected speed > 60km/h.
- Treatment: All treatments with vehicle speed above 50km/h and THW not null and expected speed > 60km/h and ACC On.

Filtering criteria
None

Factors
None

Performance indicators (PIs)
- FCW warnings

Chunking
None

Data
Events where driver is braking within 2 seconds before warning is excluded.
Only Brake response within 1.5 seconds after FCW warning is considered as a reaction due to the warning.

Statistical Methods
- 2 sample T-test.

Results
- Mean Brake reaction times
  1. Baseline: 0.519 sec
  2. Treatment: 0.514 sec

No statistical significant difference in brake response time between Baseline and Treatment.

Conclusions
There is not enough evidence to say that the use of ACC + FCW increases the reaction time to reach the brake pedal after the FCW warning.
Hypothesis: Focus on forward roadway in crash relevant events is lower when using ACC+FCW

Comparison situations
- **Baseline**: All baselines with vehicle speed above 50km/h and THW are not null and expected speed > 60 km/h.
- **Treatment**: All treatments with vehicle speed above 50km/h and THW are not null and expected speed > 60 km/h and ACC ON (Active) and plus five seconds after ACC shut off.

Filtering criteria
- Vehicle speed > 50 km/h
- THW is not null
- Expected speed > 60 km/h

Factors
Looking at the road vs not looking at the road

Performance indicators (PIs)
Count of events.

Chunking
None

Data
76 crash relevant events.

Statistical Methods
Odds ratios with confidence intervals.

Results
Odds ratios show a significant decrease in the probability of looking away from the road in crash relevant events in treatment compared to baseline (Table 42).

**Table 42: Odds Ratios for focus on forward roadway in crash relevant events (passenger cars, ACC+FCW).**

<table>
<thead>
<tr>
<th></th>
<th>Odds Ratios</th>
<th>Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crash Relevant Events</td>
<td>0.20</td>
<td>0.04-0.96</td>
</tr>
</tbody>
</table>

Conclusions
The probability of looking away from road in safety critical situations was observed to be significantly lower while using ACC+FCW.
Hypothesis: In normal (non-conflict) driving, focus and level of engagement on secondary tasks will increase when drivers use ACC+FCW

Comparison situations
- **Baseline**: All baselines with vehicle speed above 50km/h and THW are not null and expected speed > 60 km/h.
- **Treatment**: All treatments with vehicle speed above 50km/h and THW are not null and expected speed > 60 km/h and ACC ON (Active) and plus five seconds after ACC shut off.

Filtering criteria
- Vehicle speed > 50 km/h
- THW is not null
- Expected speed > 60 km/h

Factors
Secondary Task (yes / no).

Performance indicators (PIs)
Count of events for:
- General Secondary Task
- Use of Nomadic Device
- Manual Secondary Task
- Visual Secondary Task
- Cognitive Secondary Task

Chunking
None

Data
416 normal driving epochs with video annotation.

Statistical Methods
Odds ratios with confidence intervals.
Results

Odds ratios indicate a significant increase of secondary tasks and visual secondary tasks in treatment compared to baseline (Table 43). Occurrence of manual and cognitive tasks did not change between treatment and baseline.

Table 43: Odds Ratios for focus and level of engagement on secondary tasks (passenger cars, ACC+FCW).

<table>
<thead>
<tr>
<th></th>
<th>Odds Ratios</th>
<th>Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Secondary Task</td>
<td>2.61*</td>
<td>1.25-5.45</td>
</tr>
<tr>
<td>Use of Nomadic Device</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Manual Secondary Task</td>
<td>1.80</td>
<td>0.86-3.75</td>
</tr>
<tr>
<td>Visual Secondary Task</td>
<td>3.03*</td>
<td>1.18-7.80</td>
</tr>
<tr>
<td>Cognitive Secondary Task</td>
<td>1.74</td>
<td>0.68-4.44</td>
</tr>
</tbody>
</table>

Conclusions

While using ACC+FCW drivers engage in secondary tasks more often. More specifically, while using ACC+FCW car drivers were three times more likely to engage in visual secondary tasks, compared to baseline.
Annex 2: Hypotheses results for cars: LDW+IW

Hypothesis: With LDW+IW available, the number of lateral crash relevant events will be reduced.

Comparison situations

- **Baseline**: All baselines with vehicle speed above 60km/h and lane markings present
- **Treatment**: All treatments with vehicle speed above 60km/h and LDW ON\(^4\) (Active)

Filtering criteria

See Comparison situations.

Factors

None

Performance indicators (PIs)

Count of lateral\(^5\) crash relevant events.

Chunking

None

Data

133 lateral crash relevant events

Statistical Methods

Odds ratios with confidence intervals.

Results

Odds ratios show a decrease in the probability of experiencing lateral crash relevant events when LDW is available, but the difference is not significant.

<table>
<thead>
<tr>
<th>Crash Relevant Events</th>
<th>Odds Ratios</th>
<th>Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.91</td>
<td>0.46-1.77</td>
</tr>
</tbody>
</table>

Conclusions

\(^4\) Note that while data selection was based on LDW activation, LDW and IW overlap in availability/usage to 97.2 % in the dataset (3 % less IW usage/availability). Hence it is not possible to make a meaningful separation of these functions in the dataset, and simplifying the analysis by selecting data based on LDW active is guaranteed.

\(^5\) E.g. driver leaving the lane and performing an emergency recovery maneuver
Drivers did not experience a reduction in the number of lateral crash relevant events when using LDW+IW
Hypothesis: LDW (and IW6) influences lateral driving performance

Comparison situations

- **Baseline**: All baselines with vehicle speed above 60km/h and lane markings available (lane marking type is recognized and quality is high).
- **Treatment**: All treatments with vehicle speed above 60km/h and lane markings available (lane marking type is recognized and quality is high) and LDW is active.

Filtering criteria

- Vehicle speed > 60 km/h
- Lane markings available (lane marking type is recognized and quality is high)
- LDW active (only in Treatment)
- Heavy rain was excluded from the analysis

Factors

- Road Type (rural, urban, motorway)

Performance indicators (PIs)

- Median lateral offset from the middle lane (MLO)
- Mean of steering wheel angle (MSW)
- Standard deviation of yaw rate (SYR)

Chunking

180 s per chunk aggregated with a median function.

Data

All of the available data in DB divided *per driver*.

Statistical Methods

2-way repeated measures ANOVA within factors Road Type (rural, urban, motorway) and Time (baseline, treatment).

---

Note that while data selection for this hypothesis is based on LDW activation, LDW and IW (for cars only) overlap in availability/usage to 97.2 % in the dataset (3 % less IW usage/availability). Hence it is not possible to make a meaningful separation of these functions in the dataset, and the below conclusions are valid for IW as used in cars as well.
Results

In Treatment, MLO was significantly higher than in Baseline for Truck drivers and MSW was significantly higher for Car drivers (the Time factor in Table 45; p<0.05). In the car data, Road type significantly influenced MSW, MLO and SYR.

Table 45: Significant Results: lateral driving performance (passenger cars).

<table>
<thead>
<tr>
<th>PI</th>
<th>Effect</th>
<th>df</th>
<th>Error df</th>
<th>F</th>
<th>p</th>
<th>Effect Size</th>
<th>M (baseline)</th>
<th>SE (baseline)</th>
<th>M (treatment)</th>
<th>SE (treatment)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cars</td>
<td>MSW</td>
<td>Time</td>
<td>1</td>
<td>41</td>
<td>4.457</td>
<td>0.041</td>
<td>0.098</td>
<td>0.859</td>
<td>0.113</td>
<td>0.731</td>
</tr>
<tr>
<td>Trucks</td>
<td>MLO</td>
<td>Time</td>
<td>1</td>
<td>28</td>
<td>6.574</td>
<td>0.016</td>
<td>0.190</td>
<td>1.59</td>
<td>0.04</td>
<td>1.68</td>
</tr>
<tr>
<td>Cars</td>
<td>MSW</td>
<td>Road Type</td>
<td>2</td>
<td>82</td>
<td>21.47</td>
<td>&lt;0.001</td>
<td>0.344</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cars</td>
<td>MLO</td>
<td>Road Type</td>
<td>2</td>
<td>86</td>
<td>40.43</td>
<td>&lt;0.001</td>
<td>0.485</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cars</td>
<td>SYR</td>
<td>Road Type</td>
<td>2</td>
<td>86</td>
<td>244.7</td>
<td>&lt;0.001</td>
<td>0.851</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 37: Median lateral offset (passenger cars).
Conclusions

LDW use improved lateral control to some extent. For the three PIs tested, Truck drivers exhibited a higher MLO in treatment compared to baseline, but no change in SYR or MSW. Car drivers exhibited a lower MSW in treatment compared to baseline, but no change in MLO or SYR.
Hypothesis: LDW+IW increases night driving

If the availability of LDW+IW had increased drivers’ night driving during the treatment period, one would expect this to be reflected through increased LDW + IW system usage when it is dark. After all, the assumption underlying the hypothesis is that drivers might rely on the system to drive more under potentially drowsy conditions.

Comparison situations

- **Baseline**: Trips that constitute the first half of the time (per driver) driven during the treatment period.
- **Treatment**: Trips that constitute the second half of the time (per driver) driven during the treatment period.

Filtering criteria

None

Factors

- Road type: any or motorway
- Weather: any or rain

Performance indicators (PIs)

LDW usage\(^7\) when it is dark.

Chunking

None.

Data

Trips were required to be at least 5 min long and to have speed = 0 less than 20% of the time. Drivers who made less than 10 trips or had driven less than 20 hours were excluded. The data was paired according to *driver ID*.

Statistical Methods

The analysis followed closely the analysis of the U2 hypothesis “The use of LDW+IW increases over time”. Here we used a paired (according to the *driver ID*) t-test and [1] to investigate whether the usage of LDW+IW when it is dark increases over the treatment period.

\(^7\) Note that while data selection was based on LDW activation, LDW and IW overlap in availability/usage to 97.2% in the dataset (3% less IW usage/availability). Hence it is not possible to make a meaningful separation of these functions in the dataset, and simplifying the analysis by selecting data based on LDW active is warranted.
Results

There was no increase in LDW + IW usage when it is dark (Table 46). In fact, the trend seems to be toward less usage of LDW+IW at night as the treatment period continued.

As a separate note, it was not possible to quantify the impact of LDW on night driving based on the trips in the baseline period, because, for most of the drivers, the trips in the baseline period were conducted in a different season mostly summer) compared to the trips in the treatment period (mostly winter).

Table 46: Results from testing whether LDW+IW usage increased during night driving in the treatment period.

<table>
<thead>
<tr>
<th>Factors</th>
<th>Response variables</th>
<th>1st half of treatment</th>
<th>2nd half of treatment</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road: any</td>
<td>LDW usage</td>
<td>86%</td>
<td>83%</td>
<td>3% decrease.</td>
</tr>
<tr>
<td>Lighting: dark</td>
<td>Time travelled (h):</td>
<td>8 946</td>
<td>15 793</td>
<td>p-value: 0.10</td>
</tr>
<tr>
<td>Weather: any</td>
<td>Distance travelled (km):</td>
<td>51 087</td>
<td>86 827</td>
<td></td>
</tr>
<tr>
<td>Road: motorway</td>
<td>LDW usage</td>
<td>91%</td>
<td>83%</td>
<td>8% decrease.</td>
</tr>
<tr>
<td>Lighting: dark</td>
<td>Time travelled (h):</td>
<td>1 393</td>
<td>2 628</td>
<td>p-value: 0.10</td>
</tr>
<tr>
<td>Weather: any</td>
<td>Distance travelled (km):</td>
<td>133 870</td>
<td>242 030</td>
<td></td>
</tr>
<tr>
<td>Road: motorway</td>
<td>LDW usage</td>
<td>96 %</td>
<td>86%</td>
<td>10% decrease.</td>
</tr>
<tr>
<td>Lighting: dark</td>
<td>Time travelled (h):</td>
<td>243</td>
<td>478</td>
<td>p-value: 0.038</td>
</tr>
<tr>
<td>Weather: rain</td>
<td>Distance travelled (km):</td>
<td>22 657</td>
<td>42 476</td>
<td></td>
</tr>
</tbody>
</table>

Conclusions

We did not find evidence in support of the hypothesis that LDW system increases night driving.
Hypothesis: LDW + IW increases the use of turn indicators in lane change situations

Comparison situations
- **Baseline**: all trips made during the baseline period
- **Treatment**: all trips made during the treatment period

Filtering criteria
None

Factors
- Road type: both any and motorway
- Weather: both any and rain

Performance indicators (PIs)
- Number of lane changes in which turn indicator was used.
- Total number of lane changes

Chunking
None

Data
All data from drivers with at least 100 km driven in baseline and treatment. Trips were required to be at least 5 min long and to have speed = 0 less than 20% of the time.

Statistical Methods
Binominal model

Results
We observed that the probability to conduct a lane change (LC) using turn indicator (TI) was higher during the treatment period. The results are summarized in Table 47.
## Table 47: Significant results: use of turn indicator in lane change situations (passenger cars).

<table>
<thead>
<tr>
<th>Factors</th>
<th>Response variables</th>
<th>Baseline</th>
<th>Treatment</th>
<th>Total</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Road: any</td>
<td>LC with TI:</td>
<td>38794</td>
<td>49319</td>
<td>88113</td>
<td>TI usage in LC increased from 64% to 74% p-value: 0</td>
</tr>
<tr>
<td></td>
<td>LC without TI:</td>
<td>21798</td>
<td>17274</td>
<td>39072</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total:</td>
<td>60592</td>
<td>66593</td>
<td>60592</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Road: motorway</td>
<td>LC with TI:</td>
<td>19910</td>
<td>26680</td>
<td>46590</td>
<td>TI usage in LC increased from 70% to 83% p-value: 0</td>
</tr>
<tr>
<td></td>
<td>LC without TI:</td>
<td>8626</td>
<td>5452</td>
<td>14078</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total:</td>
<td>28536</td>
<td>32132</td>
<td>46590</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Road: any</td>
<td>LC with TI:</td>
<td>31657</td>
<td>39039</td>
<td>70696</td>
<td>TI usage in LC increased from 68% to 77% p-value: 0</td>
</tr>
<tr>
<td></td>
<td>LC without TI:</td>
<td>14707</td>
<td>11785</td>
<td>26492</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total:</td>
<td>46364</td>
<td>50824</td>
<td>70696</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Road: motorway</td>
<td>LC with TI:</td>
<td>2626</td>
<td>3512</td>
<td>6138</td>
<td>TI usage in LC increased from 72% to 84% p-value: 0</td>
</tr>
<tr>
<td></td>
<td>LC without TI:</td>
<td>1038</td>
<td>666</td>
<td>1704</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total:</td>
<td>3664</td>
<td>4178</td>
<td>6138</td>
<td></td>
</tr>
</tbody>
</table>

## Conclusions

The probability to conduct a lane change (LC) using turn indicator (TI) increased by 10%.
Hypothesis: In normal (non-conflict) driving, focus and level of engagement on secondary tasks will increase when drivers use LDW+IW

Comparison situations

- **Baseline**: All baselines with vehicle speed above 60km/h and lane markings available (lane marking type is recognized and quality is high).
- **Treatment**: All treatments with vehicle speed above 60km/h and lane markings available (lane marking type is recognized and quality is high) and LDW is active.

Filtering criteria

- Vehicle speed > 60 km/h
- Lane markings available (lane marking type is recognized and quality is high)
- LDW active (only in Treatment)

Factors

- Secondary Task (yes / no)

Performance indicators (PIs)

- Count of events for:
  - General Secondary Task
  - Use of Nomadic Device
  - Manual Secondary Task
  - Visual Secondary Task
  - Cognitive Secondary Task

Chunking

- None

Data

- 416 normal driving epochs with video annotation.

Statistical Methods

- Odds ratios with confidence intervals.

Results

\[\text{Note that while data selection was based on LDW activation, LDW and IW overlap in availability/usage to 97.2 \% in the dataset (3 \% less IW usage/availability). Hence it is not possible to make a meaningful separation of these functions in the dataset, and simplifying the analysis by selecting data based on LDW active is guaranteed.}\]
Odds ratios indicate a significant increase of secondary tasks and use of nomadic device in treatment compared to baseline (Table 48). Occurrence of manual, visual and cognitive tasks did not change between treatment and baseline.

Table 48: Odds Ratios for focus and level of engagement on secondary tasks (passenger cars, LDW+IW).

<table>
<thead>
<tr>
<th></th>
<th>Odds Ratios</th>
<th>Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Secondary Task</td>
<td>1.53*</td>
<td>1.04-2.27</td>
</tr>
<tr>
<td>Use of Nomadic Device</td>
<td>2.81*</td>
<td>1.19-6.65</td>
</tr>
<tr>
<td>Manual Secondary Task</td>
<td>1.27</td>
<td>0.84-1.90</td>
</tr>
<tr>
<td>Visual Secondary Task</td>
<td>1.28</td>
<td>0.72-2.25</td>
</tr>
<tr>
<td>Cognitive Secondary Task</td>
<td>0.91</td>
<td>0.54-1.52</td>
</tr>
</tbody>
</table>

Conclusions

While using LDW+IW drivers engaged in secondary tasks more often during normal driving (non-conflict driving). More specifically, when LDW+IW were active, car drivers used nomadic devices three times more, compared to baseline.
Hypothesis: Focus and level of engagement on secondary tasks just prior to Crash Relevant Events (CRE) will be higher when drivers are using ACC+ FCW+LDW

Comparison situations

- **Baseline**: All baselines with vehicle speed above 50km/h and THW are not null and expected speed > 60 km/h or **Baseline**: All baselines with vehicle speed above 60km/h and lane markings available (lane marking type is recognized and quality is high).

- **Treatment**: All treatments with vehicle speed above 50km/h and THW are not null and expected speed > 60 km/h and ACC ON (Active) and plus five seconds after ACC shut off or **Treatment**: All treatments with vehicle speed above 60km/h and lane markings available (lane marking type is recognized and quality is high) and LDW is active.

Filtering criteria

- Vehicle speed > 50 km/h
- THW is not null
- Expected speed > 60 km/h
  - or
- Vehicle speed > 60 km/h
- Lane markings available (lane marking type is recognized and quality is high)
- LDW active (only in Treatment)

Factors

Secondary Task (yes / no)

Performance indicators (PIs)

Count of events for:

- General Secondary Task
- Use of Nomadic Device
- Manual Secondary Task
- Visual Secondary Task
- Cognitive Secondary Task
Chunking

None

Data

102 crash relevant events with video annotation.

Statistical Methods

Odds ratios with confidence intervals.

Results

Odds ratios indicate no change between treatment and baseline for all type of secondary tasks (Table 49).

Table 49: Odds Ratios for focus and level of engagement on secondary tasks just prior to crash relevant events (passenger cars, ACC+FCW or LDW).

<table>
<thead>
<tr>
<th>Secondary Task</th>
<th>Odds Ratios</th>
<th>Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Secondary Task</td>
<td>1.29</td>
<td>0.54-3.07</td>
</tr>
<tr>
<td>Use of Nomadic Device</td>
<td>1.58</td>
<td>0.46-5.42</td>
</tr>
<tr>
<td>Manual Secondary Task</td>
<td>1.42</td>
<td>0.58-3.49</td>
</tr>
<tr>
<td>Visual Secondary Task</td>
<td>1.56</td>
<td>0.68-3.59</td>
</tr>
<tr>
<td>Cognitive Secondary Task</td>
<td>1.06</td>
<td>0.36-3.11</td>
</tr>
</tbody>
</table>

Conclusions

While using ACC, FCW and LDW, car drivers were not more likely to be engaged in secondary tasks prior to crash-relevant events.
Hypothesis: Use of LDW + IW decreases driver attention to forward roadway

Comparison situations
- Baseline: All trips made during the baseline period
- Treatment: All trips made during the treatment period

Filtering criteria
None

Factors
None

Performance indicators (PIs)
LDW and IW warnings

Chunking
None

Data
Analysis was made on annotated data from 134 events where LDW or IW issued warnings.

Statistical Methods
Calculation of Risk Ratio with 95% confidence interval

Results

<table>
<thead>
<tr>
<th></th>
<th>Looking at Road Ahead</th>
<th>Not looking at Road Ahead</th>
<th>odds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>23</td>
<td>45</td>
<td>1.96</td>
</tr>
<tr>
<td>Treatment</td>
<td>15</td>
<td>49</td>
<td>3.27</td>
</tr>
</tbody>
</table>

Risk ratio = 1.16  CI [ 0.93 ; 1.44]

The risk that the driver is not looking at the road ahead when there is a LDW or IW warning situation is higher when the LDW+IW is activated (Treatment) compared to not activated (Baseline), but this increase (odds ratio=1.67) is not significant.

Conclusions
The data does not support the hypothesis that the LDW+IW system decreases driver attention to the forward roadway.
Hypothesis: Focus on forward roadway in crash relevant events is lower when using LDW + IW

Comparison situations

- **Baseline**: All baselines with vehicle speed above 60km/h and lane markings available (lane marking type is recognized and quality is high).
- **Treatment**: All treatments with vehicle speed above 60km/h and lane markings available (lane marking type is recognized and quality is high) and LDW is active\(^9\).

Filtering criteria

- Vehicle speed > 60 km/h
- Lane markings available (lane marking type is recognized and quality is high)
- LDW active (only in Treatment)

Factors

Looking at the road vs not looking at the road.

Performance indicators (PIs)

Count of events

Chunking

None

Data

96 crash relevant events.

Statistical Methods

Odds ratios with confidence intervals.

Results

Odds ratios did not show a significant change in the probability of looking away from the road in treatment compared to baseline during crash relevant events (Table 51).

---

\(^9\) Note that while data selection was based on LDW activation, LDW and IW overlap in availability/usage to 97.2% in the dataset (3% less IW usage/availability). Hence it is not possible to make a meaningful separation of these functions in the dataset, and simplifying the analysis by selecting data based on LDW active is guaranteed.
Table 51: Odds Ratios for focus on forward roadway in crash relevant events (passenger cars, LDW+IW).

<table>
<thead>
<tr>
<th>Crash Relevant Events</th>
<th>Odds Ratios</th>
<th>Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.08</td>
<td>0.84-5.20</td>
</tr>
</tbody>
</table>

Conclusions

The probability of the driver looking away from the forward roadway when safety critical situations occur was not significantly different when drivers were using LDW+IW compared to when they were not. Hence the hypothesis was not supported by the data.
Hypothesis: Use of LDW + IW decreases drowsy driving

Comparison situations

- Baseline: All baselines with vehicle speed above 60km/h and IW warning available.
- Treatment: All treatments with vehicle speed above 60km/h and IW\textsuperscript{10} warning available.

Filtering criteria

See Comparison situations.

Factors

None

Performance indicators (PIs)

Warnings issued by IW (IW detects drowsiness reliably, hence the frequency of warnings issued can be used to assess the frequency of instances of driver drowsiness)

Chunking

None

Data

Input data:
The total time duration of the trips where an Impairment Warning was issued compared to the total time duration of the trips where no Impairment Warning was issued, in Baseline and Treatment respectively.

Statistical Methods

Calculation of Risk Ratio with 95% confidence interval.

Results

\textsuperscript{10} Note that while data selection was based on LDW activation, LDW and IW overlap in availability/usage to 97.2 % in the dataset (3 % less IW usage/availability). Hence it is not possible to make a meaningful separation of these functions in the dataset, and simplifying the analysis by selecting data based on LDW active is guaranteed.
Table 52: Analysis data on frequency of drowsy driving (passenger cars, LDW+IW).

<table>
<thead>
<tr>
<th></th>
<th>Sum of trip durations where a warning was issued</th>
<th>Sum of trip durations where no warning was issued</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>164</td>
<td>2888</td>
</tr>
<tr>
<td>Treatment</td>
<td>107</td>
<td>2298</td>
</tr>
</tbody>
</table>

Risk Ratio: 0.825 CI [0.65, 1.05]
Not significant

Conclusions
Use of IW did not alter the frequency of Impairment Warnings issued. Hence the hypothesis that use of LDW+IW decreases drowsy driving is not supported in this dataset.
Annex 3: Hypotheses results for cars: Speed Limiter Cruise Control (SL+CC)

Hypothesis: Using SL decreases the average speed

Comparison situations
See the “baseline sampling” section of the methodology part of D6.2.
- Baseline: Random sampled chunks according to exposure.
- Treatment: Treatment data are the chunks where the percentage of time with SL in use > 5%.

Filtering criteria
Chunks are filtered before sampling from the baseline according to the following:
- Average speed >5km/h.
- Map speed limit information available

Factors
Speed limits (30, 50, 70, 90, 110, 130 km/h.)

Performance indicators (PIs)
- Chunked Average Speed.

Chunking
The chunk process is the same for all hypotheses: See “chunking process at the French VMC” section in D6.2.

Data
- 35 drivers, which have sufficient number of accumulated kilometres ( >5000 km) in Baseline and Treatment was used for the analyses. Unknown Roads and speed limits are not included in the analyses.

Statistical Methods
See the introducing “methods for ABA analysis” section in D6.2.
- Analyse tool: SAS software (PROC GLIMMIX).
Results

Figure 39: SL effect on average speed per speed limit.

Table 53: Results for average speed differences.

<table>
<thead>
<tr>
<th>Factor (Speed limits)</th>
<th>Least squares estimation for average speed Baseline / SL Active</th>
<th>Lower bound Baseline / SL Active</th>
<th>Upper bound Baseline / SL Active</th>
<th>Type III fixed effects P-value</th>
<th>Increase Km/h</th>
<th>Lower bound effect</th>
<th>Upper bound effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 km/h</td>
<td>28.70 / 30.77</td>
<td>27.1 / 29.1</td>
<td>30.3 / 32.4</td>
<td>&lt;.0001</td>
<td>2.07</td>
<td>1.59</td>
<td>2.55</td>
</tr>
<tr>
<td>50 km/h</td>
<td>31.77 / 33.41</td>
<td>30.4 / 32.1</td>
<td>33.1 / 34.8</td>
<td>&lt;.0001</td>
<td>1.64</td>
<td>1.45</td>
<td>1.81</td>
</tr>
<tr>
<td>70 km/h</td>
<td>54.32 / 56.65</td>
<td>52.4 / 54.7</td>
<td>56.3 / 58.6</td>
<td>&lt;.0001</td>
<td>2.33</td>
<td>1.69</td>
<td>2.87</td>
</tr>
<tr>
<td>90 km/h</td>
<td>70.19 / 70.94</td>
<td>67.7 / 68.4</td>
<td>72.7 / 73.4</td>
<td>0.0006</td>
<td>0.75</td>
<td>0.31</td>
<td>1.26</td>
</tr>
<tr>
<td>110 km/h</td>
<td>94.04 / 95.82</td>
<td>90.9 / 92.7</td>
<td>97.2 / 99.0</td>
<td>&lt;.0001</td>
<td>1.78</td>
<td>1.18</td>
<td>2.38</td>
</tr>
<tr>
<td>130 km/h</td>
<td>115.56 / 115.38</td>
<td>111.3 / 111.1</td>
<td>119.8 / 119.6</td>
<td>0.4875</td>
<td>-0.18</td>
<td>-0.7</td>
<td>0.33</td>
</tr>
</tbody>
</table>

Conclusions

The function SL increased significantly the average speed in all driving contexts except for motorways (130km/h limited roads).

Factor analyses show a similar effect for all the situations, but the average speed increase is never above 3km/h, and mostly below 2km/h.
Hypothesis: Using SL will reduce over speeding occurrences.

Comparison situations

This kind of hypothesis needs to be analyzed with an event approach. As these events of interest are rare, they all need to be stored as the treatment data, while a corresponding baseline needs to be extracted. This is analogous to a case-control study.

- Baseline: Randomly sampled chunks from treatment data set (system available)
- Treatment: Chunks where an over speeding event is present.
- In that case, what we call "Baseline" is extracted from the treatment part of the overall data. We get a final data set containing chunks with and without the event (corresponding PI=0 or 1), and with and without system in use (System used=0 or 1). The fitted model is a logistic model (link=LOGIT) that computes the likelihood of the event of interest being present according to system usage. This kind of model allow for computing the odd ratios between system active and not active.

Filtering criteria

Chunks are filtered before selection according to the following parameters:

- Average speed >5km/h.
- Map speed limit information available

Factors

- Speed limit (30, 50, 70, 90, 110, 130 km/h)

Baseline and treatment data are stratified according to speed limits and separate analysis are conducted.

Performance indicators (PIs)

- Presence of an over speeding event in the chunk.
- System usage: Equal to one if system is used more than 5% of the chunk time, equal to 0 instead.

Chunking

The chunk process is the same for all hypotheses: See “chunking process at the French VMC” section in D6.2.

Data

35 drivers, which have sufficient number of accumulated kilometres (>5000 km) in Baseline and Treatment was used for the analyses. Unknown Roads and speed limits are not included in the analyses.
Statistical Methods

See the introducing “methods for EBA analysis” section in D6.2.

Analyse tool: SAS software (PROC GLIMMIX).

Results

Table 54: Estimated odds ratios and significance for over-speeding events.

<table>
<thead>
<tr>
<th>Factor (Speed limits)</th>
<th>Type III fixed effects p-value</th>
<th>Estimated effect</th>
<th>Lower bound</th>
<th>Upper bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 km/h</td>
<td>&lt;0.0001</td>
<td>1.34</td>
<td>1.22</td>
<td>1.47</td>
</tr>
<tr>
<td>50 km/h</td>
<td>0.0018</td>
<td>0.94</td>
<td>0.91</td>
<td>0.98</td>
</tr>
<tr>
<td>70 km/h</td>
<td>&lt;0.0001</td>
<td>1.30</td>
<td>1.22</td>
<td>1.39</td>
</tr>
<tr>
<td>90 km/h</td>
<td>&lt;0.0001</td>
<td>0.52</td>
<td>0.49</td>
<td>0.55</td>
</tr>
<tr>
<td>110 km/h</td>
<td>&lt;0.0001</td>
<td>0.43</td>
<td>0.39</td>
<td>0.47</td>
</tr>
<tr>
<td>130 km/h</td>
<td>&lt;0.0001</td>
<td>0.46</td>
<td>0.40</td>
<td>0.52</td>
</tr>
</tbody>
</table>

Conclusions

Very few data are available for 30 and 70 km/h limited roads, and although significance is high for the drivers taken into account, too few drivers with complete data are available to conclude about a real effect for the entire population.

The results for the other speed limits are much more reliable because data is more consistent. From 90 to 130km/h limited roads the likelihood of exceeding the speed limit while using the SL is half that of exceeding the speed limit under normal conditions (without using either system). The effect is very small, although significant, on 50km/h roads, with a tendency to reduce probability of exceeding the speed limit.

The effect of the SL on the over speeding events was higher for high speed limits, with a reduction of up to 50% when using the system.
Hypothesis: Using SL will reduce strong jerk occurrences.

Comparison situations

This kind of hypothesis needs to be analyzed with an event approach. As these events of interest are rare, they all need to be stored as the treatment data, while a corresponding baseline needs to be extracted. This is analogous to a case-control study.

- Baseline: Randomly sampled chunks from treatment data set (system available)
- Treatment: Chunks where a strong jerk event is present.
- In that case, what we call "Baseline" is extracted from the treatment part of the overall data. We get a final data set containing chunks with and without the event (corresponding PI=0 or 1), and with and without system in use (System used=0 or 1). The fitted model is a logistic model (link=LOGIT) that computes the likelihood of the event of interest being present according to system usage. This kind of model allow for computing the odd ratios between system active and not active.

Filtering criteria

Chunks are filtered before selection according to the following parameters:

- Average speed >5km/h.
- Map speed limit information available

Factors

- Speed limit (30, 50, 70, 90, 110, 130 km/h)

Baseline and treatment data are stratified according to speed limits and separate analysis are conducted.

Performance indicators (PIs)

- Presence of a strong jerk event in the chunk.
- System usage: Equal to one if system is used more than 5% of the chunk time, equal to 0 instead.

Chunking

The chunk process is the same for all hypotheses: See “chunking process at the French VMC” section in D6.2.

Data

35 drivers, which have sufficient number of accumulated kilometres ( >5000 km) in Baseline and Treatment was used for the analyses. Unknown Roads and speed limits are not included in the analyses.
Statistical Methods

See the introducing “methods for EBA analysis” section in D6.2.

Analyse tool: SAS software (PROC GLIMMIX).

Results

Table 55: Estimated odds ratios and significance for strong jerk events occurrence 130 km/h roads do not provide enough events for models convergence.

<table>
<thead>
<tr>
<th>Factor (Speed limits)</th>
<th>Type III fixed effects p-value</th>
<th>Estimated effect</th>
<th>Lower bound</th>
<th>Upper bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 km/h</td>
<td>0.0047</td>
<td>1.31</td>
<td>1.09</td>
<td>1.57</td>
</tr>
<tr>
<td>50 km/h</td>
<td>0.4622</td>
<td>0.98</td>
<td>0.93</td>
<td>1.03</td>
</tr>
<tr>
<td>70 km/h</td>
<td>0.004</td>
<td>0.78</td>
<td>0.67</td>
<td>0.93</td>
</tr>
<tr>
<td>90 km/h</td>
<td>&lt;0.0001</td>
<td>0.67</td>
<td>0.59</td>
<td>0.77</td>
</tr>
<tr>
<td>110 km/h</td>
<td>0.1596</td>
<td>0.82</td>
<td>0.62</td>
<td>1.08</td>
</tr>
<tr>
<td>130 km/h</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Conclusions

Strong jerk events are not frequent, especially on high speed roads where speed profiles are smoother. Collected data is not sufficient for model convergence on 130km/h roads, and few kilometres are collected on 30 and 70km/h roads.

SL effect is non-significant on 50 and 110km/h roads. SL effect is detected as positive on 90km/h roads leading to a likelihood of observing a strong jerk event of 0.67 times that while driving under normal conditions.

To summarize the SL effect, it is likely to be a positive effect (reduction of the probability of observing a strong jerk event) although small and not significant on many conditions.
Hypothesis: Using SL will reduce critical time gap occurrences.

Comparison situations

This kind of hypothesis needs to be analyzed with an event approach. As these events of interest are rare, they all need to be stored as the treatment data, while a corresponding baseline needs to be extracted. This is analogous to a case-control study.

- Baseline: Randomly sampled chunks from treatment data set (system available)
- Treatment: Chunks where a critical time gap event is present.

In that case, what we call "Baseline" is extracted from the treatment part of the overall data. We get a final data set containing chunks with and without the event (corresponding PI=0 or 1), and with and without system in use (System used=0 or 1). The fitted model is a logistic model (link=LOGIT) that computes the likelihood of the event of interest being present according to system usage. This kind of model allow for computing the odd ratios between system active and not active.

Filtering criteria

Chunks are filtered before selection according to the following parameters:

- Average speed >5km/h.
- Map speed limit information available

Factors

- Speed limit (30, 50, 70, 90, 110, 130 km/h)

Baseline and treatment data are stratified according to speed limits and separate analysis are conducted.

Performance indicators (PIs)

- Presence of a critical time gap event in the chunk.
- System usage: Equal to one if system is used more than 5% of the chunk time, equal to 0 instead.

Chunking

The chunk process is the same for all hypotheses: See “chunking process at the French VMC” section in D6.2.

Data

35 drivers, which have sufficient number of accumulated kilometres (>5000 km) in Baseline and Treatment was used for the analyses. Unknown Roads and speed limits are not included in the analyses.
Statistical Methods

See the introducing “methods for EBA analysis” section in D6.2.
Analyse tool: SAS software (PROC GLIMMIX).

Results

Table 56: Estimated odds ratios and significance for critical time gap events occurrence.

<table>
<thead>
<tr>
<th>Factor (Speed limits)</th>
<th>Type III fixed effects p-value</th>
<th>Estimated effect</th>
<th>Lower bound</th>
<th>Upper bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 km/h</td>
<td>0.0011</td>
<td>0.56</td>
<td>0.40</td>
<td>0.79</td>
</tr>
<tr>
<td>50 km/h</td>
<td>0.0007</td>
<td>1.13</td>
<td>1.05</td>
<td>1.21</td>
</tr>
<tr>
<td>70 km/h</td>
<td>0.2177</td>
<td>0.92</td>
<td>0.80</td>
<td>1.05</td>
</tr>
<tr>
<td>90 km/h</td>
<td>0.1568</td>
<td>0.94</td>
<td>0.85</td>
<td>1.03</td>
</tr>
<tr>
<td>110 km/h</td>
<td>0.0121</td>
<td>0.87</td>
<td>0.78</td>
<td>0.97</td>
</tr>
<tr>
<td>130 km/h</td>
<td>&lt;0.0001</td>
<td>1.31</td>
<td>1.19</td>
<td>1.45</td>
</tr>
</tbody>
</table>

Conclusions

The ability of the SL system to modify critical time gap occurrence probability is only significant for 30, 50, and 130 km/h roads. As previously stated, 30km/h roads results are not reliable because of the small amount of collected data.

On 50 km/h, the SL system multiplies by 1.13 the likelihood of observing a critical time gap event when driving with the system compared to normal conditions. The same negative impact is observed on 130km/h limited roads, with a likelihood of observing a critical time gap event when driving with the system compared to normal conditions increased by a factor of 1.3.
Hypothesis: Using SL will reduce hard braking occurrences.

Comparison situations

This kind of hypothesis needs to be analyzed with an event approach. As these events of interest are rare, they all need to be stored as the treatment data, while a corresponding baseline needs to be extracted. This is analogous to a case-control study.

- **Baseline:** Randomly sampled chunks from treatment data set (system available)
- **Treatment:** Chunks where a hard braking event is present.

In that case, what we call "Baseline" is extracted from the treatment part of the overall data. We get a final data set containing chunks with and without the event (corresponding PI=0 or 1), and with and without system in use (System used=0 or 1). The fitted model is a logistic model (link=LOGIT) that computes the likelihood of the event of interest being present according to system usage. This kind of model allow for computing the odd ratios between system active and not active.

Filtering criteria

Chunks are filtered before selection according to the following parameters:

- Average speed >5km/h
- Map speed limit information available

Factors

- Speed limit (30, 50, 70, 90, 110, 130 km/h)

Baseline and treatment data are stratified according to speed limits and separate analysis are conducted.

Performance indicators (PIs)

- Presence of a hard braking event in the chunk.
- System usage: Equal to one if system is used more than 5% of the chunk time, equal to 0 instead.

Chunking

The chunk process is the same for all hypotheses: See “chunking process at the French VMC” section in D6.2.

Data

35 drivers, which have sufficient number of accumulated kilometres ( >5000 km) in Baseline and Treatment was used for the analyses. Unknown Roads and speed limits are not included in the analyses.

Statistical Methods

See the introducing “methods for EBA analysis” section in D6.2.

Analyse tool: SAS software (PROC GLIMMIX).
## Results

Table 57: Estimated odds ratios and significance for hard braking events occurrence.

<table>
<thead>
<tr>
<th>Factor (Speed limits)</th>
<th>Type III fixed effects p-value</th>
<th>Estimated effect</th>
<th>Lower bound</th>
<th>Upper bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 km/h</td>
<td>0.1339</td>
<td>1.13</td>
<td>0.96</td>
<td>1.34</td>
</tr>
<tr>
<td>50 km/h</td>
<td>&lt;.0001</td>
<td>0.89</td>
<td>0.85</td>
<td>0.94</td>
</tr>
<tr>
<td>70 km/h</td>
<td>0.0007</td>
<td>0.77</td>
<td>0.67</td>
<td>0.90</td>
</tr>
<tr>
<td>90 km/h</td>
<td>&lt;.0001</td>
<td>0.70</td>
<td>0.62</td>
<td>0.78</td>
</tr>
<tr>
<td>110 km/h</td>
<td>0.4393</td>
<td>0.89</td>
<td>0.67</td>
<td>1.19</td>
</tr>
<tr>
<td>130 km/h</td>
<td>0.47</td>
<td>0.74</td>
<td>0.33</td>
<td>1.67</td>
</tr>
</tbody>
</table>

## Conclusions

The ability of the SL system to modify hard braking occurrences probability is only significant for 50, 70, and 90 km/h roads. As previously stated, 30km/h roads results are not reliable because of the small amount of collected data.

When the effect is significant, the range goes from 0.89 for 50km/h to 0.7 for 90km/h roads. For example, on 90km/h limited roads the likelihood of observing a hard braking event when driving with the system compared to normal conditions is decreased by a factor of 0.7.

SL system effect on hard braking occurrences is positive, with people using the system having a reduction of the odd of approximately 30%.
Hypothesis: Using SL (CC) will reduce incident occurrences.

Comparison situations

Two different approaches are adopted here. The first one is a simple aggregated analysis with the following data:

- Baseline-ABA: All baseline
- Treatment-ABA: Treatment data (SL and CC available, but not always active).

The second way to study SL and CC impact on incident frequency is to analyze it using an event approach. As these events of interest are rare (incidents), they all need to be stored as the treatment data, while a corresponding baseline needs to be extracted. This is analogous to a case-control study.

- Baseline-EBA: Randomly sampled chunks from treatment data set (system available)
- Treatment-EBA:Chunks where an incident event is present.

These two approaches are valid for both SL and CC.

In that case, what we call "Baseline" is extracted from the treatment part of the overall data. We get a final data set containing chunks with and without the event (corresponding PI=0 or 1), and with and without system in use (System used=0 or 1). The fitted model is a logistic model (link=LOGIT) that computes the likelihood of the event of interest being present according to system usage. This kind of model allow for computing the odd ratios between system active and not active.

Filtering criteria

Chunks are filtered before selection according to the following parameters:

- Average speed >5km/h
- Map speed limit information available

Factors

- Lighting (dark, day light)
- Weather (Rain, no rain)
- Experimental condition (Baseline, treatment)

No separate analysis is conducted for the speed limits.

Performance indicators (PIs)

- Number of incidents per 100 driven km.
- System usage: Equal to one if system is used more than 5% of the chunk time, equal to 0 instead.

Chunking

The chunk process is the same for all hypotheses: See “chunking process at the French VMC” section in D6.2.

Data
35 drivers, which have sufficient number of accumulated kilometres (>5000 km) in Baseline and Treatment was used for the analyses. Unknown Roads and speed limits are not included in the analyses.
Statistical Methods

For the ABA analysis, the 3 factors (experimental condition, weather, and lighting) are evaluated without the interactions in a single analyse: repeated measure ANOVA (GLMM models see methodology section in D6.2).

For the EBA part, please refer to the introducing “method for EBA analysis” section in D6.2.

Analyse tool: SAS software (PROC GLIMMIX).

Results

Repeated measures ANOVA results are presented in Table below.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Type III fixed effect F</th>
<th>Type III fixed effects p-value</th>
<th>Estimated average value of the effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline vs experiment</td>
<td>2.83</td>
<td>0.092</td>
<td>Baseline: 3.91 Treatment: 2.76</td>
</tr>
<tr>
<td>Day light vs dark</td>
<td>0.62</td>
<td>0.429</td>
<td>Day light: 3.07 Dark: 3.60</td>
</tr>
<tr>
<td>No Rain vs Rain</td>
<td>2.45</td>
<td>0.118</td>
<td>No rain: 2.72 Rain: 3.95</td>
</tr>
</tbody>
</table>

For the EBA analysis, the odds of experiencing an incident (with π being the probability of an incident) while driving with SL active is 0.6828 times the odds while driving without SL active (p-value<0.0001).

The odds of experiencing an incident while driving with CC active is 0.1648 times the odds while driving without CC (p-value<0.0001).

Conclusions

Results of the ANOVA did not show any significant effect among the three factors. There is no significant difference in the incident rate between baseline and treatment. Looking more precisely the situations where system is active leads to adopt an EBA. Incident rate decreased when driving with SL or CC active. The estimated decrease in incident rate is more important for CC.

This last effect may be due to driver’s choice to use the system when traffic is free flowing instead of the system effect itself. This effect is higher for CC usage, leading to an apparently strong positive effect, although not due to the system itself but to driver’s choice to use it depending in driving situations.
Hypothesis: Using CC decreases the average speed.

Comparison situations

See the D6.2 baseline sampling section for further details.

- **Baseline**: Random sampled chunks according to exposure. The baseline is the same as for the SL system.
- **Treatment**: For CC: Treatment data are the chunks where the percentage of time with CC in use > 5%.

Filtering criteria

Chunks are filtered before sampling from the baseline according to the following:

- Average speed >5km/h
- Map speed limit information available

Factors

Speed limit (30, 50, 70, 90, 110, 130 km/h)

Performance indicators (PIs)

Chunked Average Speed.

Chunking

The chunk process is the same for all hypotheses: See “chunking process at the French VMC” section in D6.2.

Data

35 drivers, which have sufficient number of accumulated kilometres (>5000 km) in Baseline and Treatment was used for the analyses. Unknown Roads and speed limits are not included in the analyses.

Statistical Methods

See the introducing “methods for ABA analysis” section in D6.2.

Analyse tool: SAS software (PROC GLIMMIX).

Results
Conclusions

The function CC increased significantly the average speed in all driving contexts. Factor analyses show a similar effect for all the situations, with an average speed increase of more than 10km/h.
Hypothesis: Using CC will reduce over speeding occurrences.

Comparison situations

This kind of hypothesis needs to be analyzed with an event approach. As these events of interest are rare, they all need to be stored as the treatment data, while a corresponding baseline needs to be extracted. This is analogous to a case-control study.

- Baseline: Randomly sampled chunks from treatment data set (system available)
- Treatment: Chunks where an over speeding event is present.

In that case, what we call "Baseline" is extracted from the treatment part of the overall data. We get a final data set containing chunks with and without the event (corresponding PI=0 or 1), and with and without system in use (System used=0 or 1). The fitted model is a logistic model (link=LOGIT) that computes the likelihood of the event of interest being present according to system usage. This kind of model allow for computing the odd ratios between system active and not active.

Filtering criteria

Chunks are filtered before selection according to the following parameters:

- Average speed >5km/h
- Map speed limit information available

Factors

- Speed limit (30, 50, 70, 90, 110, 130 km/h)

Baseline and treatment data are stratified according to speed limits and separate analysis are conducted.

Performance indicators (PIs)

- Presence of an over speeding event in the chunk.
- System usage: Equal to one if system is used more than 5% of the chunk time, equal to 0 instead.

Chunking

The chunk process is the same for all hypotheses: See "chunking process at the French VMC" section in D6.2.

Data

35 drivers, which have sufficient number of accumulated kilometres (>5000 km) in Baseline and Treatment was used for the analyses. Unknown Roads and speed limits are not included in the analyses.
Statistical Methods

See the introducing “methods for EBA analysis” section in D6.2.
Analyse tool: SAS software (PROC GLIMMIX).

Results

<table>
<thead>
<tr>
<th>Factor (Speed limits)</th>
<th>Type III fixed effects p-value</th>
<th>Estimated effect</th>
<th>Lower bound</th>
<th>Upper bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 km/h</td>
<td>&lt;0.0001</td>
<td>17.77</td>
<td>9.12</td>
<td>34.63</td>
</tr>
<tr>
<td>50 km/h</td>
<td>&lt;0.0001</td>
<td>3.40</td>
<td>3.17</td>
<td>3.65</td>
</tr>
<tr>
<td>70 km/h</td>
<td>&lt;0.0001</td>
<td>3.84</td>
<td>3.47</td>
<td>4.25</td>
</tr>
<tr>
<td>90 km/h</td>
<td>&lt;0.0001</td>
<td>2.18</td>
<td>2.05</td>
<td>2.32</td>
</tr>
<tr>
<td>110 km/h</td>
<td>&lt;0.0001</td>
<td>1.56</td>
<td>1.45</td>
<td>1.67</td>
</tr>
<tr>
<td>130 km/h</td>
<td>&lt;0.0001</td>
<td>0.77</td>
<td>0.71</td>
<td>0.83</td>
</tr>
</tbody>
</table>

Conclusions

Very few data are available for 30 km/h limited roads, and although significance is high for the drivers taken into account, too few drivers with complete data are available to conclude about a real effect for the entire population.

The results for the other speed limits are much more reliable because data is more consistent. From 50 to 110km/h limited roads the likelihood of exceeding the speed limit while using the CC are two to four times the likelihood of exceeding the speed limit under normal conditions (naturalistic driving without using any system). The effect of CC increase the probability of exceeding the speed on most roads, but the effect is opposite on motorways (OR=0.77). High speeds like 130km/h seem to be sufficient for a French driver, or the risk of being controlled is estimated to be higher on motorways, leading to a better compliance with the speed limits.
Hypothesis: Using CC will reduce strong jerk occurrences.

Comparison situations

This kind of hypothesis needs to be analyzed with an event approach. As these events of interest are rare, they all need to be stored as the treatment data, while a corresponding baseline needs to be extracted. This is analogous to a case-control study.

- Baseline: Randomly sampled chunks from treatment data set (system available)
- Treatment: Chunks where a strong jerk event is present.

In that case, what we call "Baseline" is extracted from the treatment part of the overall data. We get a final data set containing chunks with and without the event (corresponding PI=0 or 1), and with and without system in use (System used=0 or 1). The fitted model is a mixed logistic model (link=LOGIT) that computes the likelihood of the event of interest being present according to system usage. This kind of model allow for computing the odd ratios between system active and not active.

Filtering criteria

Chunks are filtered before selection according to the following parameters:

- Average speed >5km/h
- Map speed limit information available

Factors

- Speed limit (30, 50, 70, 90, 110, 130 km/h)

Baseline and treatment data are stratified according to speed limits and separate analysis are conducted.

Performance indicators (PIs)

- Presence of a strong jerk event in the chunk.
- System usage: Equal to one if system is used more than 5% of the chunk time, equal to 0 instead.

Chunking

The chunk process is the same for all hypotheses: See “chunking process at the French VMC“ section in D6.2.

Data

35 drivers, which have sufficient number of accumulated kilometres (>5000 km) in Baseline and Treatment was used for the analyses. Unknown Roads and speed limits are not included in the analyses.

Statistical Methods

See the introducing “methods for EBA analysis” section in D6.2.

Analyse tool: SAS software (PROC GLIMMIX).
## Results

Table 61: Estimated odds ratios and significance for strong jerk events.

<table>
<thead>
<tr>
<th>Factor (Speed limits)</th>
<th>Type III fixed effects p-value</th>
<th>Estimated effect</th>
<th>Lower bound</th>
<th>Upper bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 km/h</td>
<td>0.033</td>
<td>0.27</td>
<td>0.08</td>
<td>0.90</td>
</tr>
<tr>
<td>50 km/h</td>
<td>&lt;0.0001</td>
<td>0.36</td>
<td>0.30</td>
<td>0.44</td>
</tr>
<tr>
<td>70 km/h</td>
<td>&lt;0.0001</td>
<td>0.41</td>
<td>0.29</td>
<td>0.57</td>
</tr>
<tr>
<td>90 km/h</td>
<td>&lt;0.0001</td>
<td>0.32</td>
<td>0.26</td>
<td>0.38</td>
</tr>
<tr>
<td>110 km/h</td>
<td>&lt;0.0001</td>
<td>0.32</td>
<td>0.26</td>
<td>0.38</td>
</tr>
<tr>
<td>130 km/h</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

## Conclusions

Strong jerk events are not frequent, especially on high speed roads where speed profiles are smoother. Collected data is not sufficient for model convergence on 130km/h roads, and few kilometres are collected on 30 and 70km/h roads.

Results are significant for all road types, showing a positive influence of the CC on the probability of observing a strong jerk event while driving. The likelihood of observing a strong jerk event when using CC was approximately 0.3 times the likelihood while driving under normal conditions (no system available). In other terms, the probability of observing this kind of event was divided by 3 when using the system.
Hypothesis: Using CC will reduce critical time gap occurrences.

Comparison situations

This kind of hypothesis needs to be analyzed with an event approach. As these events of interest are rare, they all need to be stored as the treatment data, while a corresponding baseline needs to be extracted. This is analogous to a case-control study.

- Baseline: Randomly sampled chunks from treatment data set (system available)
- Treatment: Chunks where a critical time gap event is present.

In that case, what we call "Baseline" is extracted from the treatment part of the overall data. We get a final data set containing chunks with and without the event (corresponding PI=0 or 1), and with and without system in use (System used=0 or 1). The fitted model is a logistic model (link=LOGIT) that computes the likelihood of the event of interest being present according to system usage. This kind of model allow for computing the odd ratios between system active and not active.

Filtering criteria

Chunks are filtered before selection according to the following parameters:

- Average speed >5km/h
- Map speed limit information available

Factors

- Speed limit (30, 50, 70, 90, 110, 130 km/h)

Baseline and treatment data are stratified according to speed limits and separate analysis are conducted.

Performance indicators (PIs)

- Presence of a critical time gap event in the chunk.
- System usage: Equal to one if system is used more than 5% of the chunk time, equal to 0 instead.

Chunking

The chunk process is the same for all hypotheses: See "chunking process at the French VMC" section in D6.2.

Data

35 drivers, which have sufficient number of accumulated kilometres (>5000 km) in Baseline and Treatment was used for the analyses. Unknown Roads and speed limits are not included in the analyses.

Statistical Methods

See the introducing "methods for EBA analysis" section in D6.2.

Analyse tool: SAS software (PROC GLIMMIX).
Results

Table 62: Estimated odds ratios and significance for critical time gap events.

<table>
<thead>
<tr>
<th>Factor (Speed limits)</th>
<th>Type III fixed effects p-value</th>
<th>Estimated effect</th>
<th>Lower bound</th>
<th>Upper bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 km/h</td>
<td>0.1324</td>
<td>0.21</td>
<td>0.03</td>
<td>1.60</td>
</tr>
<tr>
<td>50 km/h</td>
<td>&lt;0.0001</td>
<td>0.31</td>
<td>0.23</td>
<td>0.42</td>
</tr>
<tr>
<td>70 km/h</td>
<td>&lt;0.0001</td>
<td>0.40</td>
<td>0.33</td>
<td>0.49</td>
</tr>
<tr>
<td>90 km/h</td>
<td>&lt;0.0001</td>
<td>0.46</td>
<td>0.41</td>
<td>0.51</td>
</tr>
<tr>
<td>110 km/h</td>
<td>&lt;0.0001</td>
<td>0.68</td>
<td>0.63</td>
<td>0.73</td>
</tr>
<tr>
<td>130 km/h</td>
<td>&lt;0.0001</td>
<td>0.74</td>
<td>0.69</td>
<td>0.79</td>
</tr>
</tbody>
</table>

Conclusions

The ability of the CC system to modify critical time gap occurrences probability was significant for all the speed limits. As previously stated, 30km/h roads results are not reliable because of the small amount of collected data.

On 50 km/h roads, the CC system multiplied the likelihood of observing a critical time gap event by 0.31 when driving with the system compared to normal conditions. The same positive impact was observed for all the speed limits, although the effect is less important for high speed limits.

On motorways, the likelihood of observing a critical time gap event when driving with the system compared to normal conditions was multiplied by 0.74.
Hypothesis: Using CC will reduce hard braking occurrences.

Comparison situations

This kind of hypothesis needs to be analyzed with an event approach. As these events of interest are rare, they all need to be stored as the treatment data, while a corresponding baseline needs to be extracted. This is analogous to a case-control study.

- Baseline: Randomly sampled chunks from treatment data set (system available)
- Treatment: Chunks where a hard braking event is present.

In that case, what we call "Baseline" is extracted from the treatment part of the overall data. We get a final data set containing chunks with and without the event (corresponding PI=0 or 1), and with and without system in use (System used=0 or 1). The fitted model is a logistic model (link=LOGIT) that computes the likelihood of the event of interest being present according to system usage. This kind of model allow for computing the odd ratios between system active and not active.

Filtering criteria

Chunks are filtered before selection according to the following parameters:

- Average speed >5km/h
- Map speed limit information available

Factors

- Speed limit (30, 50, 70, 90, 110, 130 km/h)

Baseline and treatment data are stratified according to speed limits and separate analysis are conducted.

Performance indicators (PIs)

- Presence of a hard braking event in the chunk.
- System usage: Equal to one if system is used more than 5% of the chunk time, equal to 0 instead.

Chunking

The chunk process is the same for all hypotheses: See “chunking process at the French VMC” section in D6.2.

Data

35 drivers, which have sufficient number of accumulated kilometres ( >5000 km) in Baseline and Treatment was used for the analyses. Unknown Roads and speed limits are not included in the analyses.

Statistical Methods

See the introducing “methods for EBA analysis” section in D6.2.

Analyze tool: SAS software (PROC GLIMMIX).
Results

Table 63: Estimated odds ratios and significance for hard braking events.

<table>
<thead>
<tr>
<th>Factor (Speed limits)</th>
<th>Type III fixed effects p-value</th>
<th>Estimated effect</th>
<th>Lower bound</th>
<th>Upper bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 km/h</td>
<td>0.1324</td>
<td>0.21</td>
<td>0.03</td>
<td>1.60</td>
</tr>
<tr>
<td>50 km/h</td>
<td>&lt;0.0001</td>
<td>0.31</td>
<td>0.23</td>
<td>0.42</td>
</tr>
<tr>
<td>70 km/h</td>
<td>&lt;0.0001</td>
<td>0.40</td>
<td>0.33</td>
<td>0.49</td>
</tr>
<tr>
<td>90 km/h</td>
<td>&lt;0.0001</td>
<td>0.46</td>
<td>0.41</td>
<td>0.51</td>
</tr>
<tr>
<td>110 km/h</td>
<td>&lt;0.0001</td>
<td>0.68</td>
<td>0.63</td>
<td>0.73</td>
</tr>
<tr>
<td>130 km/h</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Conclusions

The ability of the CC system to modify hard braking occurrences probability was significant for all roads except 30km/h roads. As previously stated, 30km/h roads results were not reliable because of the small amount of collected data and collected data is not sufficient for model convergence on 130km/h roads.

Results are significant on most road types showing a positive effect. For example, on 90km/h limited roads the likelihood of observing a hard braking event when driving with the system compared to normal conditions was multiplied by 0.46.

CC system effect on hard braking occurrences was positive, with people using the system having a reduction of the likelihood of approximately 50%.
Hypothesis: Using CC will reduce incident occurrences.

CC effect on incidents is already analyzed in the “Using SL will reduce incident occurrences” hypothesis.
Hypothesis: Having SRS decreases the average speed

The speed regulation system (SRS) consist of both speed limiter and cruise control, and so the condition named “having SRS” refer to the entire experiment data, taking into account both systems active, and also data when none of them is active. In addition, SL and CC cannot be active at the same time.

Comparison situations

- Baseline: Random sampled chunks according to exposure.
- Treatment: Random sampled chunks according to exposure.

Filtering criteria

Chunks are filtered before sampling from the baseline according to the following:

1. Average speed >5km/h
2. Map speed limit information available

Factors

Speed limit (30, 50, 70, 90, 110, 130 km/h)

Performance indicators (PIs)

Average speed per chunk.

Chunking

The chunk process is the same for all hypotheses: See “chunking process at the French VMC” section in D6.2.

Data

35 drivers, which have sufficient number of accumulated kilometres (>5000 km) in Baseline and Treatment was used for the analyses. Unknown Roads are not included in the analyses.

Statistical Methods

See the introducing “methods for ABA analysis” section in D6.2.

Analyse tool: SAS software (PROC GLIMMIX).
Results

![chart](image)

**Figure 41: Having SRS effect on average speed per speed limit.**

**Table 64: Results for average speed differences between baseline and experiment.**

<table>
<thead>
<tr>
<th>Factor (Speed limits)</th>
<th>Least squares estimation for average speed Baseline / Treatment</th>
<th>Lower bound Baseline / Treatment</th>
<th>Upper bound Baseline / Treatment</th>
<th>Type III fixed effects P-value</th>
<th>Increase Km/h</th>
<th>Lower bound effect</th>
<th>Upper bound effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 km/h</td>
<td>28.60 / 29.25</td>
<td>27.1 / 27.8</td>
<td>30.1 / 30.7</td>
<td>0.0002</td>
<td>0.65</td>
<td>0.31</td>
<td>0.99</td>
</tr>
<tr>
<td>50 km/h</td>
<td>31.82 / 32.27</td>
<td>30.4 / 30.9</td>
<td>33.2 / 33.7</td>
<td>&lt;.0001</td>
<td>0.45</td>
<td>0.33</td>
<td>0.58</td>
</tr>
<tr>
<td>70 km/h</td>
<td>54.91 / 55.22</td>
<td>53.1 / 53.4</td>
<td>56.7 / 57.0</td>
<td>0.1224</td>
<td>0.31</td>
<td>0.08</td>
<td>0.69</td>
</tr>
<tr>
<td>90 km/h</td>
<td>69.75 / 70.31</td>
<td>67.4 / 67.9</td>
<td>72.1 / 72.7</td>
<td>&lt;.0001</td>
<td>0.56</td>
<td>0.27</td>
<td>0.85</td>
</tr>
<tr>
<td>110 km/h</td>
<td>94.74 / 96.63</td>
<td>92.2 / 94.1</td>
<td>97.3 / 99.2</td>
<td>&lt;.0001</td>
<td>1.89</td>
<td>1.55</td>
<td>2.24</td>
</tr>
<tr>
<td>130 km/h</td>
<td>118.83 / 121.70</td>
<td>116.7 / 119.6</td>
<td>121.0 / 123.8</td>
<td>&lt;.0001</td>
<td>2.87</td>
<td>2.64</td>
<td>3.1</td>
</tr>
<tr>
<td>All conditions</td>
<td>62.37 / 65.43</td>
<td>57.91 / 60.97</td>
<td>66.83 / 69.89</td>
<td>&lt;.0001</td>
<td>3.06</td>
<td>2.87</td>
<td>3.24</td>
</tr>
</tbody>
</table>

**Conclusions**

The function SRS increased the average speed in all driving contexts except for 70km/h limited roads which did not provide as much data as other driving contexts.

Factor analyses show a similar effect for all the situations, with a small average speed increase less than 3 km/h.
Annex 4: Hypotheses results for cars: Navigation System

In Annex 4, all individual hypotheses results are presented. Because the distributions for all safety-related indicators are left skewed, non-parametric testing with Friedman ANOVA (3 conditions) is used. For post-hoc tests, Wilcoxon signed rank tests are used. No \( \alpha \)-adjustment is conducted, because data samples for urban and rural roads are independent. Since up-scaling is based on incidents only, no adjustment of \( \alpha \) for combining the results of the different PIs is necessary. Because all distributions are left skewed, it has to be corrected for outliers before calculating mean and standard deviations. This has only been done for the overall incident frequency, for all other safety indicators, means and standard deviations are not presented.

Hypothesis: Navigation systems decrease incidents while approaching decision points

Comparison situations

1. **Baseline**: All baseline trips
2. **Treatment – built-in**: All trips in condition built-in navigation system with routing function active
3. **Treatment – mobile**: All trips in condition mobile navigation system with routing function active

Filtering criteria

- Trip length > 1km
- On intersection

Factors

- Road type (rural and urban)
- Familiarity (familiar, unfamiliar) in combination with road type

Performance indicators (PIs)

- Distance events per intersection crossed
- Lateral events per intersection crossed
- Longitudinal events per intersection crossed
- All incidents per intersection crossed

Chunking

None.

Data

All of the available data in DB divided per driver.
Statistical Methods

Friedman ANOVA comparing baseline, treatment built-in and treatment mobile. Independent testing per situational condition (familiarity * road type). For post-hoc testing, Wilcoxon signed rank tests are used.
Results

Table 65: Results of Friedman ANOVAS for incident frequency

<table>
<thead>
<tr>
<th>Familiarity</th>
<th>PI</th>
<th>Rural N / df</th>
<th>Chi2</th>
<th>p</th>
<th>Urban N / df</th>
<th>Chi2</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>Distance</td>
<td>83 / 2</td>
<td>3.55</td>
<td>&lt;0.05</td>
<td>85 / 2</td>
<td>25.69</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>Lateral</td>
<td>83 / 2</td>
<td>6.95</td>
<td>&lt;0.05</td>
<td>85 / 2</td>
<td>27.98</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>Longitudinal</td>
<td>83 / 2</td>
<td>3.40</td>
<td>7.23</td>
<td>85 / 2</td>
<td>32.15</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>All</td>
<td>83 / 2</td>
<td>1.33</td>
<td></td>
<td>85 / 2</td>
<td>32.15</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Familiar</td>
<td>Distance</td>
<td>84 / 2</td>
<td>7.80</td>
<td>&lt;0.05</td>
<td>86 / 2</td>
<td>22.52</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>Lateral</td>
<td>84 / 2</td>
<td>15.38</td>
<td>&lt;0.001</td>
<td>86 / 2</td>
<td>41.06</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>Longitudinal</td>
<td>84 / 2</td>
<td>4.86</td>
<td>0.088</td>
<td>86 / 2</td>
<td>10.44</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td></td>
<td>All</td>
<td>84 / 2</td>
<td>8.16</td>
<td>&lt;0.05</td>
<td>86 / 2</td>
<td>35.41</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Unfamiliar</td>
<td>Distance</td>
<td>49 / 2</td>
<td>0.91</td>
<td></td>
<td>50 / 2</td>
<td>4.04</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lateral</td>
<td>49 / 2</td>
<td>0.40</td>
<td></td>
<td>50 / 2</td>
<td>1.42</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Longitudinal</td>
<td>49 / 2</td>
<td>1.00</td>
<td></td>
<td>50 / 2</td>
<td>0.40</td>
<td></td>
</tr>
<tr>
<td></td>
<td>All</td>
<td>49 / 2</td>
<td>0.42</td>
<td></td>
<td>50 / 2</td>
<td>3.29</td>
<td></td>
</tr>
</tbody>
</table>

Table 66: Means and standard deviation for incident frequency at intersections

<table>
<thead>
<tr>
<th>PI</th>
<th>Road type</th>
<th>Baseline m</th>
<th>Baseline sd</th>
<th>Built-in m</th>
<th>Built-in sd</th>
<th>Mobile m</th>
<th>Mobile sd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>Rural</td>
<td>0.0020</td>
<td>0.0038</td>
<td>0.0016</td>
<td>0.0029</td>
<td>0.0019</td>
<td>0.0069</td>
</tr>
<tr>
<td></td>
<td>Urban</td>
<td>0.0023</td>
<td>0.0027</td>
<td>0.0020</td>
<td>0.0028</td>
<td>0.0017</td>
<td>0.0057</td>
</tr>
<tr>
<td>Familiar</td>
<td>Rural</td>
<td>0.0019</td>
<td>0.0037</td>
<td>0.0018</td>
<td>0.0040</td>
<td>0.0015</td>
<td>0.0067</td>
</tr>
<tr>
<td></td>
<td>Urban</td>
<td>0.0022</td>
<td>0.0025</td>
<td>0.0020</td>
<td>0.0026</td>
<td>0.0020</td>
<td>0.0072</td>
</tr>
<tr>
<td>Unfamiliar</td>
<td>Rural</td>
<td>0.0035</td>
<td>0.0152</td>
<td>0.0017</td>
<td>0.0064</td>
<td>0.0010</td>
<td>0.0026</td>
</tr>
<tr>
<td></td>
<td>Urban</td>
<td>0.0019</td>
<td>0.0054</td>
<td>0.0008</td>
<td>0.0017</td>
<td>0.0005</td>
<td>0.0010</td>
</tr>
</tbody>
</table>

Figure 42: Incident frequency at intersections

The graphs show the results for overall incident frequency.
Conclusions

With active navigation system, there were fewer incidents at intersections on familiar routes than in the baseline condition. For unfamiliar routes, there was no effect of condition.
Hypothesis: Navigation systems decrease proportion of time with close following distance

Comparison situations
- **Baseline**: All baseline trips
- **Treatment – built-in**: All trips in condition built-in navigation system with routing function active
- **Treatment – mobile**: All trips in condition mobile navigation system with routing function active

Performance indicators (PIs)
- Proportion of critical THW
- Proportion of critical TTC

Filtering criteria
- Trip length > 1km
- Car-follow situation
- \( v > 0.5 \text{ km/h} \)

Factors
- Road type (highway, rural, urban)
- Familiarity (familiar, unfamiliar) in combination with road type

Chunking
None.

Data
All of the available data in DB divided per driver.

Statistical Methods
Friedman ANOVA comparing baseline, treatment built-in and treatment mobile. Independent testing per situational condition (familiarity * road type). For post-hoc testing, Wilcoxon signed rank tests are used.

Results
Post-hoc tests show that in urban areas the proportion of critical TTC is reduced for both types of navigation systems as compared to baseline. This effect is based on familiar trips only. On rural roads, the proportion of critical TTC is reduced for both navigation systems. Again, there is no difference between the two types of system. If we split based on familiarity, there is a tendency for familiar trips and no effect for unfamiliar trips.

For the proportion of critical THW, there is a significant decrease with the built-in device and a tendency for the mobile device in urban areas. Splitting based on familiarity gives a significant decrease for both HMI-solutions on familiar trips. On unfamiliar trips there is a tendency that the proportion of critical THW is reduced with the built-in navigation system on urban and rural roads.
Table 67: Results of Friedman ANOVAS for proportion of time with close following distance

<table>
<thead>
<tr>
<th>PI</th>
<th>Sit</th>
<th>Highway</th>
<th>Rural</th>
<th>Urban</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N / df</td>
<td>Chi2</td>
<td>p</td>
<td>N / df</td>
</tr>
<tr>
<td>% THW crit</td>
<td>All</td>
<td>85 / 2</td>
<td>0.61</td>
<td>1.60</td>
</tr>
<tr>
<td></td>
<td>Fam</td>
<td>82 / 2</td>
<td>2.99</td>
<td>1.93</td>
</tr>
<tr>
<td></td>
<td>unfam</td>
<td>46 / 2</td>
<td>1.00</td>
<td>7.72</td>
</tr>
<tr>
<td>% TTC crit</td>
<td>All</td>
<td>85 / 2</td>
<td>0.55</td>
<td>15.93</td>
</tr>
<tr>
<td></td>
<td>Fam</td>
<td>82 / 2</td>
<td>2.58</td>
<td>5.46</td>
</tr>
<tr>
<td></td>
<td>unfam</td>
<td>46 / 2</td>
<td>2.58</td>
<td>1.29</td>
</tr>
</tbody>
</table>

Figure 43: Proportion of time with critical THW (left) and critical TTC (right) split for road type. The graphs show the results for overall testing.

Conclusions

In urban areas and on rural roads, less close following distances occurred when a navigation system was used. There was no consistent difference between the two HMI-solutions.
Hypothesis: Navigation systems decrease lane-keeping errors

Comparison situations

- **Baseline**: All baseline trips
- **Treatment – built-in**: All trips in condition built-in navigation system with routing function active
- **Treatment – mobile**: All trips in condition mobile navigation system with routing function active

Performance indicators (PIs)

- Proportion of critical TLC
- Number of lane exceedances / hour

Filtering criteria

- Trip length > 1km
- Lane position detected
- \( v > 0.5 \text{ km/h} \)

Factors

- Road type (highway, rural, urban)
- Familiarity (familiar, unfamiliar) in combination with road type

Chunking

None.

Data

All of the available data in DB divided per driver.

Statistical Methods

Friedman ANOVA comparing baseline, treatment built-in and treatment mobile. Independent testing per situational condition (familiarity * road type). For post-hoc testing, Wilcoxon signed rank tests are used.

Results

Post-hoc tests show that in urban areas the proportion of critical TLC is reduced with the built-in navigation system compared to baseline. If we split by familiarity, this effect can be found for unfamiliar but not for familiar trips. Furthermore, in urban areas the frequency of lane exceedances is reduced with the built-in navigation system compared to baseline and compared to the mobile device. If we split by familiarity, the frequency of lane exceedances is lower with the built-in device compared to the two other conditions on familiar and unfamiliar trips.
Table 68: Results of Friedman ANOVAs for lane-keeping errors.
PI = performance indicator, N = number of drivers, df = degrees of freedom, p = p-value.

<table>
<thead>
<tr>
<th>PI</th>
<th>Sit</th>
<th>Highway</th>
<th>Rural</th>
<th>Urban</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N / df</td>
<td>Chi2</td>
<td>p</td>
<td>N / df</td>
</tr>
<tr>
<td>% TLC crit</td>
<td>All</td>
<td>84 / 2</td>
<td>0.31</td>
<td>85 / 2</td>
</tr>
<tr>
<td></td>
<td>Fam</td>
<td>83 / 2</td>
<td>0.46</td>
<td>83 / 2</td>
</tr>
<tr>
<td></td>
<td>unfam</td>
<td>45 / 2</td>
<td>0.84</td>
<td>49 / 2</td>
</tr>
<tr>
<td>Lane exc/h</td>
<td>All</td>
<td>84 / 2</td>
<td>4.17</td>
<td>85 / 2</td>
</tr>
<tr>
<td></td>
<td>Fam</td>
<td>83 / 2</td>
<td>1.62</td>
<td>83 / 2</td>
</tr>
<tr>
<td></td>
<td>unfam</td>
<td>45 / 2</td>
<td>0.84</td>
<td>49 / 2</td>
</tr>
</tbody>
</table>

Figure 44: Proportion of time with critical time to line crossing (left) and number of lane exceedances per hour (right) separate for road type. The graphs show the results for overall testing.

Conclusions

With the built-in navigation system, lane keeping performance in urban areas was improved compared to baseline condition. There was no clear effect for the mobile device. It is not known why the built-in navigation system improves lane keeping performance compared to baseline driving.
Hypothesis: Navigation systems decrease number of hard braking events per hour

Comparison situations

- **Baseline**: All baseline trips
- **Treatment – built-in**: All trips in condition built-in navigation system with routing function active
- **Treatment – mobile**: All trips in condition mobile navigation system with routing function active

Performance indicators (PIs)

Number of hard braking events per hour

Filtering criteria

- Trip length > 1km
- \( v > 0.5 \text{ km/h} \)

Factors

- Road type (highway, rural, urban).
- Familiarity (familiar, unfamiliar) in combination with road type

Chunking

None.

Data

All of the available data in DB divided *per driver*.

Statistical Methods

Friedman ANOVA with within factor condition. For post-hoc testing, Wilcoxon signed rank tests are used.

Results

Post-hoc tests show that on urban and rural roads the number of hard braking events is reduced while using the built-in navigation system compared to baseline condition. This effect can also be found for familiar trips only.

<table>
<thead>
<tr>
<th></th>
<th>Highway</th>
<th>Rural</th>
<th>Urban</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N / df</td>
<td>Chi2</td>
<td>p</td>
</tr>
<tr>
<td>Overall</td>
<td>85 / 2</td>
<td>2.98</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Familiar</td>
<td>84 / 2</td>
<td>1.79</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Unfamiliar</td>
<td>46 / 2</td>
<td>0.65</td>
<td>0.078</td>
</tr>
</tbody>
</table>

Table 69: Results of Friedman ANOVAS for number of hard braking events per hour.

PI = performance indicator, \( N = \) number of drivers, \( df = \) degrees of freedom, \( p = \) p-value.
Conclusions

With the built-in navigation system, the number of hard braking events was reduced on rural roads and in urban areas. There was no influence of the mobile device on the number of hard braking events.
Hypothesis: Navigation systems decrease number of hard accelerations

Comparison situations

- **Baseline**: All baseline trips
- **Treatment – built-in**: All trips in condition built-in navigation system with routing function active
- **Treatment – mobile**: All trips in condition mobile navigation system with routing function active

Performance indicators (PIs)

Number of hard accelerations/ hour

Filtering criteria

- Trip length > 1km
- \( v > 0.5 \text{ km/h} \)

Factors

Road type (highway, rural, urban).

Chunking

None.

Data

All of the available data in DB divided by driver.

Statistical Methods

Friedman ANOVA with within factor condition. For post-hoc testing, Wilcoxon signed rank tests are used.

Results

Table 70: Results of Friedman ANOVAS for number of hard accelerations.

<table>
<thead>
<tr>
<th></th>
<th>Highway</th>
<th>Rural</th>
<th>Urban</th>
</tr>
</thead>
<tbody>
<tr>
<td>N / df</td>
<td>85 / 2</td>
<td>86 / 2</td>
<td>87 / 2</td>
</tr>
<tr>
<td>Chi2</td>
<td>5.75</td>
<td>0.87</td>
<td>2.78</td>
</tr>
<tr>
<td>p</td>
<td>0.57</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Conclusions

The frequency of hard acceleration events did not change with navigation system usage, controlling for road type.
Annex 5: Hypotheses results for cars: BLIS

Hypothesis: BLIS reduces use of indicator because driver assumes that there is no other car

Comparison situations
Use of turning indicator in Baseline vs. Treatment

Filtering criteria
1. Vehicle speed > 10 km/h
2. Unknown Road Types are not included in the analysis
3. LDW off

Performance indicators (PIs)
Turn indicator use in conjunction with lane change

Chunking
None

Data
Input data: Total no of lane changes with use of turn indicator compared with total no of lane changes without use of turn indicator in Baseline and Treatment. Turn indicator use must be within 3 s before a certain Lane Change to be considered as relevant.

Statistical Methods
Calculation of Risk Ratio with 95% confidence interval.

Results

<table>
<thead>
<tr>
<th></th>
<th>Lane changes with use of turn indicator</th>
<th>Lane changes without use of turn indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Baseline</strong></td>
<td>20604</td>
<td>40743</td>
</tr>
<tr>
<td><strong>Treatment</strong></td>
<td>3465</td>
<td>8047</td>
</tr>
</tbody>
</table>

Risk Ratio = 0.83 CI [0.81 ; 0.86]

Significant.

Hence, the different in use of turn indicator between Baseline and Treatment is significant. The use of Turn indicator is 10% less in Treatment compared to Baseline.
Conclusions

With BLIS, the use of turn indicator at lane changes decreased 10%.
Annex 6: Hypotheses results for trucks: ACC+FCW

Hypothesis: ACC decreases the number of critical time-headway to the leading vehicle

Comparison situations

1. **Baseline**: All baseline with ACC state off
2. **Treatment**: All treatment with ACC state active (plus 5 sec after ACC shut off)

Filtering criteria

3. Travelled time with vehicle speed not null > 5 min.
4. Vehicle speed >=50 km/h
5. THW>0 (car following)
6. Posted speed > 100 km/h
7. Minimum mileage for each driver in baseline/treatment conditions (100km)

Factors

None

Performance indicators (PIs)

Relative risk of time-headway under 0.5s per 100km

Data

All drivers (N), which have sufficient number of accumulated kilometres (>100 km) in Baseline and Treatment, were used for the analyses. N=36 for motorway (501069 km). Data were divided into heavy (GCW > 30 tons) and light (GCW <= 30 tons).

Statistical Methods

Wilcoxon signed-rank test and 2 Proportion test and 2 sample T-test
Results

![Risk of critical THW in baseline and treatment.](image)

**Table 72: Summary of results: risk of critical THW (trucks).**

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Relative risk (risk treatment / risk baseline)</th>
<th>% Increase/Reduction</th>
<th>N</th>
<th>Mileage [km]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motorway weight: any</td>
<td>0.46</td>
<td>-54.0</td>
<td>36</td>
<td>501069</td>
</tr>
<tr>
<td>Motorway weight: heavy</td>
<td>0.51</td>
<td>-49.0</td>
<td>36</td>
<td>303020</td>
</tr>
<tr>
<td>Motorway weight: light</td>
<td>0.43</td>
<td>-57.0</td>
<td>36</td>
<td>198049</td>
</tr>
</tbody>
</table>

Conclusions

The number of critical time gaps (THW<0.5 sec) to the leading vehicle was reduced by 54.0% in the overall evaluation on motorway driving. When the truck was light (weight < 30 tons), the benefit was the highest. When the truck is heavy, drivers tend to keep longer time-gaps and therefore, better safety margins in baseline as well. This reduces the benefit in treatment for this condition.
Hypothesis: ACC reduces the average speed

Comparison situations

8. **Baseline**: All baseline with ACC state off
9. **Treatment**: All treatment with ACC state active

Filtering criteria

10. Travelled time with vehicle speed not null > 5 min.
11. Vehicle speed >=50 km/h
12. THW>0 (car following)
13. Posted speed > 100 km/h
14. Minimum mileage for each driver in baseline/treatment conditions (100km)

Factors

Weight (**heavy** GCW > 30 tons, **light** GCW <= 30 tons)

Performance indicators (PIs)

Average speed

Data

All drivers (N), which have sufficient number of accumulated kilometres (>100 km) in Baseline and Treatment, were used for the analyses. N=53 for motorway (570183 km).

Statistical Methods

Repeated measures ANOVA
Results

![Figure 48: Average speed in baseline and treatment.](image.png)

Table 73: Summary of results: average speed (trucks).

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Baseline Mean</th>
<th>Treatment Mean</th>
<th>% Increase/Reduction</th>
<th>N</th>
<th>Mileage [km]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motorway</td>
<td>83.61</td>
<td>84.33</td>
<td>0.87</td>
<td>53</td>
<td>570183</td>
</tr>
</tbody>
</table>

Conclusions

The average speed increases by 0.87% when driving with ACC on motorways. Neither the factor weight nor the interaction comparison situation*weight was significant in the analysis.
Hypothesis: ACC reduces the number of incidents

Comparison situations

15. **Baseline**: All baseline with ACC state off
16. **Treatment**: All treatment with ACC state active (plus 5 sec after ACC shut off)

Filtering criteria

17. Travelled time with vehicle speed not null > 5 min
18. Vehicle speed >=50 km/h
19. THW>0 (car following)
20. Posted speed >100 km/h
21. Minimum mileage for each driver in baseline/treatment conditions (100km)

Factors

Due to low number of incidents, no factors were included

Performance indicators (PIs)

22. Number of incidents per 100 driven km based on vehicle kinematics
23. Number of incidents per 100 driven km based on video annotation

Data

All drivers (N), which have sufficient number of accumulated kilometres (>100 km) in Baseline and Treatment, were used for the analyses.

24. Number of incidents based on vehicle kinematics: N=6 for motorway (71854 km).
25. Number of incidents based on subjective video analysis: N=30 for overall (429215 km).

Statistical Methods

Wilcoxon signed-rank test and 2 Proportion test and 2 sample T-test
Results: Number of incidents based on vehicle kinematics per 100km

![Number of incidents based on vehicle kinematics per 100km (trucks).](image)

Table 74: Summary of results: number of incidents based on vehicle kinematics per 100km (trucks).

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Baseline Mean</th>
<th>Treatment Mean</th>
<th>% Increase/Reduction</th>
<th>N</th>
<th>Mileage [km]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motorway</td>
<td>0.014</td>
<td>0.009</td>
<td>-35.71 (CI = 90%, sig p = 0.086)</td>
<td>6</td>
<td>71854</td>
</tr>
</tbody>
</table>
Results: Number of incidents based on video annotation per 100km (not significant)

![Graph showing number of incidents per 100km](image)

**Figure 50: Number of incidents based on video annotation per 100km (trucks).**

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Baseline Risk (events/100km)</th>
<th>Treatment Risk (events/100km)</th>
<th>% Increase/Reduction</th>
<th>N</th>
<th>Mileage [km]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motorway</td>
<td>0.0047</td>
<td>0.00406</td>
<td>-13.6 (Not statistically significant)</td>
<td>30</td>
<td>429215</td>
</tr>
</tbody>
</table>

**Table 75: Summary of results: number of incidents based on video annotation per 100km (trucks).**

Conclusions

The number of incidents per 100km based on vehicle kinematics was reduced by 35.71% within the assessment on motorways. Those evaluated by video annotation showed a reduction of 13.6%.

The lack of significance for the video annotated critical events is likely due to the fact that the final number of events judged relevant for ACC+FCW was very small (21 events).
Hypothesis: ACC reduces the number of hard braking events

Comparison situations

26. Baseline: All baseline with ACC state off
27. Treatment: All treatment with ACC state active (plus 5 sec after ACC shut off)

Filtering criteria

28. Travelled time with vehicle speed not null > 5 min.
29. Vehicle speed >=50 km/h
30. THW>0 (car following)
31. Posted speed > 100 km/h
32. Minimum mileage for each driver in baseline/treatment conditions (100km)

Factors

None

Performance indicators (PIs)

33. Number of high decelerations per 100 driven km
34. Relative risk of strong braking reactions

Data

All drivers (N), which have sufficient number of accumulated kilometres (>100 km) in Baseline and Treatment, were used for the analyses.

35. Number of high decelerations per 100 driven km: N=6 for motorway (71854 km)
36. Number of strong braking reactions: N=30 for motorway (429215 km)

Data were divided into heavy (GCW > 30 tons) and light (GCW <= 30 tons).

Statistical Methods

Wilcoxon signed-rank test and 2 Proportion test and 2 sample T-test
Results: Number of high decelerations per 100 driven km

![Graph showing number of high decelerations per 100 driven km for trucks.](image)

**Figure 51:** Number of high decelerations per 100 driven km (trucks).

**Table 76:** Summary of results: number of high decelerations per 100 driven km (trucks).

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Baseline</th>
<th>Treatment</th>
<th>% Increase/Reduction</th>
<th>N</th>
<th>Mileage [km]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Mean</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motorway weight: any</td>
<td>19.68</td>
<td>6.69</td>
<td>-66.01</td>
<td>6</td>
<td>71854</td>
</tr>
<tr>
<td>Motorway weight: heavy</td>
<td>39.98</td>
<td>14.72</td>
<td>-63.18</td>
<td>6</td>
<td>66865</td>
</tr>
</tbody>
</table>
Results: Relative risk of strong braking reactions

![Figure 52: Relative risk of strong braking reactions (trucks).](image)

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Relative risk (risk treatment / risk baseline)</th>
<th>% Increase/Reduction</th>
<th>N</th>
<th>Mileage [km]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motorway weight: any</td>
<td>0.68</td>
<td>-32.0</td>
<td>30</td>
<td>429215</td>
</tr>
<tr>
<td>Motorway weight: heavy</td>
<td>0.62</td>
<td>-38.0</td>
<td>30</td>
<td>236154</td>
</tr>
<tr>
<td>Motorway weight: light</td>
<td>0.95</td>
<td>-5%</td>
<td>30</td>
<td>193061</td>
</tr>
</tbody>
</table>

Conclusions

The number of high decelerations per 100km was reduced by 66% within the assessment on motorways. Overall, in treatment the strong braking reactions were reduced by 32% compared to baseline.

The risk in baseline of slamming on the brakes (strong braking reactions) was smaller when the truck was light, what accounted for a high relative risk (0.95). Note that this does not mean that treatment was riskier when the truck was light, just that baseline was safer in this condition.

Combining the two PI’s using mileage as a weight, the overall reduction was 37%.
Hypothesis: ACC increases the average THW

Comparison situations

37. **Baseline**: All baselines with ACC state off
38. **Treatment**: All treatments with ACC state active

Filtering criteria

39. Travelled time with vehicle speed not null > 5 min.
40. Vehicle speed >=50 km/h
41. THW>0
42. Posted speed > 100 km/h
43. Minimum mileage for each driver in baseline/treatment conditions (100km)

Factors

Weight (**heavy** GCW > 30 tons, **light** GCW <= 30 tons)

Performance indicators (PIs)

Average time headway (THW)

Data

All drivers (N), which have sufficient number of accumulated kilometres (>100 km) in Baseline and Treatment, were used for the analyses. N=53 for motorway (570183 km).

Statistical Methods

Repeated measures ANOVA
Results

![Figure 53: Average THW in baseline and treatment (trucks).](image)

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Baseline</th>
<th>Treatment</th>
<th>% Increase/ Reduction</th>
<th>N</th>
<th>Mileage [km]</th>
</tr>
</thead>
<tbody>
<tr>
<td>motorway</td>
<td>3.52</td>
<td>3.69</td>
<td>4.78</td>
<td>53</td>
<td>570183</td>
</tr>
</tbody>
</table>

Conclusions

The average THW increases by 4.78% on motorways. Main factor weight was also significant, while the interaction comparison situation*weight was not.
Hypothesis: Focus on forward roadway in crash relevant events is lower when using FCW+ACC

Comparison situations

44. **Baseline**: All baselines with vehicle speed above 50km/h **and** THW are not null **and** posted speed > 100km/h.

45. **Treatment**: All treatments with vehicle speed above 50km/h **and** THW are not null **and** posted speed > 100km/h **and** ACC ON (Active) **and** plus five seconds after ACC shut off.

Filtering criteria

46. Vehicle speed > 50 km/h

47. THW is not null (car following)

48. Posted speed > 100km/h

49. Minimum 100km in each one of the four combinations of time (baseline, treatment) and weight (heavy, light)

Factors

Looking at the road vs. not looking at the road

Due to the small amount of events, weight was not included in the analysis

Performance indicators (PIs)

Count of events

Chunking

None

Data

28 crash relevant events

Statistical Methods

Odds ratios with confidence intervals

Results

Odds ratios show increased probability of eyes-off-road in crash relevant events in treatment compared to baseline; however, this result is not significant.

Table 79: Summary of results: focus on forward roadway in crash relevant events (trucks, ACC+FCW).

<table>
<thead>
<tr>
<th>Crash Relevant Events</th>
<th>Odds Ratios</th>
<th>Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.50</td>
<td>0.26 - 8.64</td>
</tr>
</tbody>
</table>
Conclusions

The probability of looking away from road in safety critical situations did not significantly change while using ACC+FCW. Note that the number of crash relevant events used was rather small, so results ought to be viewed more as a trend.
Hypothesis: In normal (non-conflict) driving, focus and level of engagement on secondary tasks will increase when drivers use ACC+ FCW

Comparison situations

50. **Baseline**: All baselines with vehicle speed above 50km/h and THW are not null and posted speed > 100km/h.

51. **Treatment**: All treatments with vehicle speed above 50km/h and THW are not null and posted speed > 100km/h and ACC ON (Active) and plus five seconds after ACC shut off.

Filtering criteria

52. Vehicle speed > 50 km/h
53. THW is not null (car following)
54. Posted speed > 100km/h
55. Minimum 100km in each one of the four combinations of time (baseline, treatment) and weight (heavy, light).

Factors

Secondary Task (yes / no)

Due to the small amount of events, weight was not included in the analysis

Performance indicators (PIs)

Count of events for:

56. General Secondary Task
57. Use of Nomadic Device
58. Manual Secondary Task
59. Visual Secondary Task
60. Cognitive Secondary Task

Chunking

None

Data

150 normal driving epochs with video annotation

Statistical Methods

Odds ratios with confidence intervals
Results

All odds ratios did not indicate change in the proportion of secondary tasks between treatment and baseline, further none was not significant.

Table 80: Summary of results: focus and level of engagement on secondary tasks (trucks, ACC+FCW).

<table>
<thead>
<tr>
<th>Task</th>
<th>Odds Ratios</th>
<th>Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Secondary Task</td>
<td>1.09</td>
<td>0.28 - 4.19</td>
</tr>
<tr>
<td>Use of Nomadic Device</td>
<td>4.36</td>
<td>0.36 - 53.3</td>
</tr>
<tr>
<td>Manual Secondary Task</td>
<td>0.64</td>
<td>0.14 - 2.97</td>
</tr>
<tr>
<td>Visual Secondary Task</td>
<td>3.45</td>
<td>0.50 - 23.9</td>
</tr>
<tr>
<td>Cognitive Secondary Task</td>
<td>2.09</td>
<td>0.26 - 16.9</td>
</tr>
</tbody>
</table>

Conclusions

Using ACC+FCW does not increase occurrence of secondary tasks for truck drivers.
Hypothesis: The driver changes the use of ACC over time by increasing occurrence of overriding the ACC system by using the accelerator pedal

Comparison situations
All trips in the treatment period were labeled either “before” or “after” in such a way that for each driver

61. Any trip labeled “after” was done later than any trip labeled “before”.
62. The total duration of the trips labeled “before” is (approximately) equal to the total duration of the trips labeled “after”.

We then compared the usage of accelerator pedal given ACC is active “before” (Baseline) and “after” (Treatment).

Filtering criteria
We discarded trips with unknown driver ID, and excluded drivers which have not used ACC during Baseline or Treatment, or where the usage was to a large extent unbalanced.

Factors
63. Road type: both any and motorway
64. Weight: both any and heavy (GCW > 30 tons)

Performance indicators (PIs)
Percentage of time the accelerator pedal is used given ACC is active

Chunking
None

Data
The data was paired according to driver ID. After filtering we had a total of 38 drivers.

Statistical Methods
We did extensive exploratory data analysis using the Matlab toolbox which we have developed exclusively to address this and similar hypotheses. We then performed a paired (according to driver ID) t-test in order to see whether the difference in LDW usage between Baseline (“before”) and Treatment (“after”) is statistically significant. The analysis was done separately for all possible choices of factor levels.
Results

We observed that the usage of accelerator pedal when the ACC is active decreased from 6.5% to 5.2% (road type: any) and from 6.2% to 5.2% (road type: motorway). Results are summarized in the table below. The decrease was not statistically significant (at 5% significance level).

<table>
<thead>
<tr>
<th>Factors</th>
<th>Response variables</th>
<th>Baseline (“before”)</th>
<th>Treatment (“after”)</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road: any</td>
<td>Accel. pedal usage: 6.5%</td>
<td>5.2%</td>
<td>0.9% decrease.</td>
<td></td>
</tr>
<tr>
<td>Weight: any</td>
<td>Number of trips: 2198</td>
<td>2154</td>
<td>p-value: 0.107</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ACC active (h): 1 725</td>
<td>1 640</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Road: motorway</td>
<td>Accel. pedal usage: 6.7%</td>
<td>7.3%</td>
<td>0.6% decrease.</td>
<td></td>
</tr>
<tr>
<td>Weight: any</td>
<td>ACC active (h): 2 923</td>
<td>2 345</td>
<td>p-value: 0.106</td>
<td></td>
</tr>
</tbody>
</table>

Figure 54: Accelerator pedal usage (given ACC is active) change per driver (trucks). The red dots represent different drivers.

Conclusions

We observed a decrease (not significant) in usage of accelerator pedal when overriding the state of ACC. The drivers pushed the accelerator pedal on average 6.1% of time ACC was active.
Hypothesis: Using ACC+FCW, driver's reaction time (time to reach the brake pedal) will increase if ACC is used most of the time and decrease if only the FCW function is actually used

Comparison situations

65. ACC\textsubscript{On}+FCW\textsubscript{On}: Whole treatment with vehicle speed above 50km/h and THW is not null and posted speed > 100km/h and ACC ON and plus five seconds after ACC shut off.

66. ACC\textsubscript{Off}+FCW\textsubscript{On}: Whole treatment with vehicle speed above 50km/h and THW is not null and posted speed > 100km/h and ACC OFF (five seconds added in the definition Treatment1 are excluded here so that we avoid an overlap between conditions).

In both conditions 1 and 2, FCW was ON.

Filtering criteria

67. Vehicle speed > 50 km/h
68. THW is not null (car following)
69. Posted speed > 100km/h

Factors

Due to the small amount of events, no factors were included in the analysis

Performance indicators (PIs)

70. Reaction time: Time from the beginning of a forward collision warning until the brake pedal position reaches 5% within a window of three seconds. If the driver was braking within three seconds prior to the warning, this particular reaction time was disregarded.

71. Percentage of early reaction: Percentage of time the drivers initiate braking before the warning was issued within a window of three seconds.

Chunking

None

Data

258 warnings from 16 drivers for PI “reaction time” and 332 warnings from 20 drivers for PI “percentage of early reaction” were used.

Statistical Methods

The non-parametric Wilcoxon signed rank test was used.
Results

Results were only significant for the PI *Percentage of early reaction*, $Z = -2.11$, $p = 0.035$, indicating a higher percentage during the ACCoff+FCWon.

Conclusions

We found no significant difference between the reaction time in ACCon+FCWon and ACCoff+FCWon. Nevertheless, the number or drivers who initiated a reaction before the warning was issued was significantly higher in ACCoff+FCWon, i.e., when only FCW was used and ACC was OFF. In addition, due to the small amount of events, weight was not included in the analysis.
Annex 7: Hypotheses results for trucks: LDW

Hypothesis: LDW influences lateral driving performance

Comparison situations

- **Baseline**: All baselines with vehicle speed above 60km/h and lane markings available (lane marking type is recognized and quality is high).
- **Treatment**: All treatments with vehicle speed above 60km/h and lane markings available (lane marking type is recognized and quality is high) and LDW is active.

Filtering criteria

- Vehicle speed > 60 km/h
- Lane markings available (lane marking type is recognized and quality is high)
- LDW active (only in Treatment)
- Only Motorways

Factors

- Fleets (Volvo fleet in UK or NL)
- Weight (**heavy** GCW > 30 tons, **light** GCW <= 30 tons)

Performance indicators (PIs)

- Median lateral offset (MLO) – distance to the lane on the right (right-hand traffic) or on the left (left-hand traffic)
- Mean of steering wheel angle (MSW)
- Standard deviation of yaw rate (SYR)

Chunking

180 s per chunk aggregated with a median function.

Data

All of the available data in DB divided per driver.

Statistical Methods

3-way repeated measures ANOVA with within factors **Weight (heavy, light)** and **Time (baseline, treatment)**; and between factor **Fleet**.

Results

In Treatment condition, MLO was significantly higher than in Baseline condition (Time factor; p<0.05; Table 82; Figure 55). The other main factors and interactions were not significant for MLO. Load effect was significant (p<0.05) for MSW and SYR. A significant (p<0.05) interaction between load and fleet for MSW was also found. None of the other main factors and interactions for MSW and SYR was significant.
Table 82: Significant results: lateral driving performance (trucks).

<table>
<thead>
<tr>
<th>PI</th>
<th>Effect</th>
<th>df</th>
<th>Error df</th>
<th>F</th>
<th>p</th>
<th>Effect Size</th>
<th>M (baseline)</th>
<th>SE (baseline)</th>
<th>M (treatment)</th>
<th>SE (treatment)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MLO</td>
<td>Time</td>
<td>1</td>
<td>28</td>
<td>6.574</td>
<td>0.016</td>
<td>0.190</td>
<td>1.597</td>
<td>0.033</td>
<td>1.681</td>
<td>0.011</td>
</tr>
<tr>
<td>MSW</td>
<td>Weight</td>
<td>1</td>
<td>28</td>
<td>8.933</td>
<td>0.006</td>
<td>0.242</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MSW</td>
<td>Weight x Fleet</td>
<td>1</td>
<td>1</td>
<td>73.80</td>
<td>&lt;0.001</td>
<td>0.725</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SYR</td>
<td>Weight</td>
<td>1</td>
<td>28</td>
<td>18.45</td>
<td>&lt;0.001</td>
<td>0.397</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 55: Median lateral offset (trucks).

Conclusions

LDW did influence lateral control. Truck drivers exhibited a higher MLO in treatment than in baseline suggesting drivers were driving further away from road edge. This behaviour tends to increase safety margins.
Hypothesis: LDW increases night driving

Results

This hypothesis is not applicable to trucks as their trips follow the schedule irrespective of whether it is day or night.
Hypothesis: LDW increases the use of turn indicators in lane change situations

Comparison situations
- **Baseline**: all trips made during the baseline period.
- **Treatment**: all trips made during the treatment period.

Filtering criteria
None

Factors
- Road type: any or motorway
- Weight: (heavy GCW > 30 tons, light GCW <= 30 tons)

Performance indicators (PIs)
- Number of lane changes in which turn indicator was used.
- Total number of lane changes

Chunking
None

Data
All data from drivers with at least 100 km driven in baseline and treatment. Trips were required to be at least 5 min long and to have speed = 0 less than 20% of the time.

Statistical Methods
Binominal model

Results
We observed that the probability to conduct a lane change (LC) using turn indicator (TI) was higher during the treatment period. The results are summarized in Table 62.
Table 83: Significant results: use of turn indicator in lane change situations (trucks).

<table>
<thead>
<tr>
<th>Factors</th>
<th>Response variables</th>
<th>Baseline</th>
<th>Treatment</th>
<th>Total</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road: any</td>
<td>LC with TI:</td>
<td>26227</td>
<td>41563</td>
<td>67790</td>
<td>TI usage in LC increased from 73% to 76% p-value: 0</td>
</tr>
<tr>
<td>Weight: any</td>
<td>LC without TI:</td>
<td>9801</td>
<td>13007</td>
<td>22808</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total:</td>
<td>36028</td>
<td>54570</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Road: motorway</td>
<td>LC with TI:</td>
<td>16378</td>
<td>25424</td>
<td>41802</td>
<td>TI usage in LC increased from 81% to 84% p-value: 0</td>
</tr>
<tr>
<td>Weight: any</td>
<td>LC without TI:</td>
<td>3964</td>
<td>4897</td>
<td>8861</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total:</td>
<td>20342</td>
<td>30321</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Road: any</td>
<td>LC with TI:</td>
<td>18123</td>
<td>28155</td>
<td>46278</td>
<td>TI usage in LC increased from 78% to 80% p-value: 1.6e-14</td>
</tr>
<tr>
<td>Weight: heavy</td>
<td>LC without TI:</td>
<td>5221</td>
<td>6936</td>
<td>12157</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total:</td>
<td>23344</td>
<td>35091</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Road: motorway</td>
<td>LC with TI:</td>
<td>16378</td>
<td>25412</td>
<td>41790</td>
<td>TI usage in LC increased from 81% to 84% p-value: 0</td>
</tr>
<tr>
<td>Weight: heavy</td>
<td>LC without TI:</td>
<td>3964</td>
<td>4894</td>
<td>8858</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total:</td>
<td>20342</td>
<td>30306</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Conclusions

The probability to conduct a lane change (LC) using turn indicator (TI) increased by 3%.
Hypothesis: In normal (non-conflict) driving, focus and level of engagement on secondary tasks will increase when drivers use LDW

Comparison situations

- **Baseline**: All baselines with vehicle speed above 60km/h and lane markings available (lane marking type is recognized and quality is high).
- **Treatment**: All treatments with vehicle speed above 60km/h and lane markings available (lane marking type is recognized and quality is high) and LDW is active.

Filtering criteria

- Vehicle speed > 60 km/h
- Lane markings available (lane marking type is recognized and quality is high)
- LDW active (only in Treatment)

Factors

Secondary Task (yes / no)
Due to the small amount of events, weight was not included in the analysis

Performance indicators (PIs)

Count of events for:
- General Secondary Task
- Use of Nomadic Device
- Manual Secondary Task
- Visual Secondary Task
- Cognitive Secondary Task

Chunking

None

Data

150 normal driving epochs with video annotation.

Statistical Methods

Odds ratios with confidence intervals.
Results

All odds ratios did not indicate change in the proportion of secondary tasks between treatment and baseline, further none was not significant (Table 84).

Table 84: Odds Ratio for focus and level of engagement on secondary tasks (trucks, LDW).

<table>
<thead>
<tr>
<th></th>
<th>Odds Ratio</th>
<th>Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Secondary Task</td>
<td>0.87</td>
<td>0.42-1.80</td>
</tr>
<tr>
<td>Use of Nomadic Device</td>
<td>1.31</td>
<td>0.21-8.08</td>
</tr>
<tr>
<td>Manual Secondary Task</td>
<td>0.86</td>
<td>0.38-1.93</td>
</tr>
<tr>
<td>Visual Secondary Task</td>
<td>0.96</td>
<td>0.28-3.38</td>
</tr>
<tr>
<td>Cognitive Secondary Task</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

Conclusions

Using LDW did not increase secondary tasks for truck drivers during normal driving.
Hypothesis: Focus and level of engagement on secondary tasks just prior to Crash Relevant Events (CRE) will be higher when drivers are using FCW+ACC+LDW

Comparison situations

- **Baseline**: All baselines with vehicle speed above 50km/h and THW are not null and posted speed > 100km/h or **Baseline**: All baseline with vehicle speed above 60km/h and lane markings available (lane marking type is recognized and quality is high).

- **Treatment**: All treatments with vehicle speed above 50km/h and THW are not null and posted speed > 100km/h and ACC ON (Active) and plus five seconds after ACC shut off or **Treatment**: All treatments with vehicle speed above 60km/h and lane markings available (lane marking type is recognized and quality is high) and LDW is active.

Filtering criteria

- Vehicle speed > 50 km/h
- THW is not null
- Posted speed > 100km/h
  - or
- Vehicle speed > 60 km/h
- Lane markings available (lane marking type is recognized and quality is high)
- LDW active (only in Treatment)

Factors

Secondary Task (yes / no)

Due to the small amount of events, weight was not included in the analysis

Performance indicators (PIs)

Count of events for:

- General Secondary Task
- Use of Nomadic Device
- Manual Secondary Task
- Visual Secondary Task
- Cognitive Secondary Task

Chunking

None
Data

40 crash relevant events with video annotation.

Statistical Methods

Odds ratios with confidence intervals.

Results

Odds ratios indicate no change between treatment and baseline for all type of secondary tasks (Table 85) with a trend toward secondary tasks being less represented in treatment than in baseline.

Table 85: Odds Ratio for focus and level of engagement on secondary tasks just prior to crash relevant events (trucks, ACC+FCW or LDW).

<table>
<thead>
<tr>
<th>Secondary Task</th>
<th>Odds Ratio</th>
<th>Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Secondary Task</td>
<td>1.71</td>
<td>0.30-9.71</td>
</tr>
<tr>
<td>Use of Nomadic Device</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Manual Secondary Task</td>
<td>1.31</td>
<td>0.31-5.49</td>
</tr>
<tr>
<td>Visual Secondary Task</td>
<td>0.87</td>
<td>0.20-3.77</td>
</tr>
<tr>
<td>Cognitive Secondary Task</td>
<td>1.00</td>
<td>0.09-10.87</td>
</tr>
</tbody>
</table>

Conclusions

While using ACC, FCW, and LDW, truck drivers were not more likely to be engaged in secondary tasks during crash-relevant events.
Hypothesis: Focus on forward roadway in crash relevant events is lower when using LDW

Comparison situations
- **Baseline**: All baselines with vehicle speed above 60km/h and lane markings available (lane marking type is recognized and quality is high).
- **Treatment**: All treatments with vehicle speed above 60km/h and lane markings available (lane marking type is recognized and quality is high) and LDW is active.

Filtering criteria
- Vehicle speed > 60 km/h
- Lane markings available (lane marking type is recognized and quality is high)
- LDW active (only in Treatment)

Factors
Looking at the road vs. not looking at the road

Due to the small amount of events, weight was not included in the analysis

Performance indicators (PIs)
Count of events

Chunking
None

Data
30 crash relevant events

Statistical Methods
Odds ratios with confidence intervals.

Results
Odds ratios show no increased probability of eyes-off-road in crash relevant events in treatment compared to baseline; however, this result is not significant (Table 86).

<table>
<thead>
<tr>
<th>Odds Ratio</th>
<th>Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Crash Relevant Events</strong></td>
<td>1.18</td>
</tr>
</tbody>
</table>

Conclusions
The probability of looking away from road in safety critical situations did not significantly change while using LDW.
Hypothesis: With LDW available, the number of lateral crash relevant events will be reduced.

Comparison situations

- **Baseline**: All baselines with vehicle speed above 60km/h and lane markings present
- **Treatment**: All treatments with vehicle speed above 60km/h and LDW ON (Active)

Filtering criteria

See comparison situations

Factors

Due to the small amount of events, no factors were included in the analysis

Performance indicators (PIs)

Count of lateral\(^{11}\) crash relevant events.

Chunking

None

Data

19 lateral crash relevant events

Statistical Methods

Odds ratios with confidence intervals.

Results

Odds ratios show a decrease in the probability of experiencing lateral crash relevant events when LDW is available, but the difference is not significant (Table 87).

<table>
<thead>
<tr>
<th>Crash Relevant Events</th>
<th>Odds Ratio</th>
<th>Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.53</td>
<td>0.17-1.59</td>
</tr>
</tbody>
</table>

Conclusions

Driver experience a reduction in the number of lateral crash relevant events when using LDW, but this reduction is not significant.

\(^{11}\) E.g. driver leaving the lane and performing an emergency recovery maneuver
Annex 8: Video annotation in euroFOT

The developed method has the purpose of defining the procedure of video annotation used in euroFOT and will also form one part of a standard procedure for future FOT projects. The manual annotation of video is one kind of data treatment that is carried out once the data is collected in a NDS/FOT; when transferring the data to the database a pre-processing procedure is applied, and for hypotheses testing on a statistical basis another preparation is needed. The method described below starts at the point where data is collected, pre-processed and uploaded to the database, and ends when the review is finished and annotations are uploaded to the database.

After a filtering process were scenario conditions and kinematic triggers were applied all the collected data a list of candidate events is generated for manual review and annotation. In the tool for viewing these event data, FOTware, the annotator can view the video together with the objective data, play the clip at different speeds, start and stop and choose signals to plot. That enables the annotator to understand the event and what was causing it. The level of severity of the event is then defined on the following scale: Normal Driving, Increased Risk, Crash-Relevant Conflict, Near-Crash and Crash according to the following flow chart:
**Event Severity**

Definitions according to code book "Variables for Video Based Annotation in euroFOT" v0.1 20120125

<table>
<thead>
<tr>
<th>Event</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal Driving</td>
<td>No safety-relevant circumstance is present.</td>
</tr>
<tr>
<td>Increased Risk Event</td>
<td>Any circumstance that increases the level of risk associated with driving, but does not result in any of the events defined below. Examples include: driver control error without proximal hazards being present; driver judgment error such as unsafe tailgating or excessive speed; or cases in which drivers are distracted to an unsafe level. This increased risk is usually caused by the driver him/herself and not by others.</td>
</tr>
<tr>
<td>Crash-relevant Conflict</td>
<td>Any circumstance where the subject vehicle performs an evasive maneuver to avoid a road departure or crash with another vehicle, pedestrian, cyclist, animal or object, still with the possibility of a later/less effortful reaction. In case of unclear conflict and evasive maneuver an &quot;oops- reaction&quot; of the driver indicates a critical moment and thus a crash-relevant event. If no &quot;oops-reactions&quot; is seen the driver is assumed to be aware of the situation and the event is not considered to be relevant. However, in case of a clear conflict and evasive maneuver an &quot;oops&quot;-reaction is not necessary.</td>
</tr>
<tr>
<td>Near-Crash</td>
<td>Any circumstance that requires a rapid evasive maneuver by the subject vehicle, or any other vehicle, pedestrian, cyclist or animal to avoid a crash or road departure. A rapid evasive maneuver is defined as steering, braking, accelerating, or any combination of control inputs that approaches the limits of the vehicle's capabilities.</td>
</tr>
<tr>
<td>Crash</td>
<td>Any contact with an object, either moving or fixed, or ground (with exception of continuous contact to roadway by vehicle's tire tread), at any speed in which kinetic energy is measurably transferred or dissipated</td>
</tr>
</tbody>
</table>

The event must be classed as increased risk or higher to qualify for further analysis. Variables used for annotations of those relevant events are listed and defined in the code book (latest version euroFOT_Codebook_basic_version_v1.1_20120201 available upon request at the Swedish VMC).

The quality of the coding is monitored by the supervisor in several ways: directly by guiding the annotators in difficult cases (during individual coding), by spot-checking random events, via regular annotator meetings to discuss questions and difficult cases, and by testing the
inter-rater reliability. The inter-rater test showed a “substantial agreement” between the different annotators (Fleiss’ Kappa $k=0.69$).

Annotators were recruited among the students studying engineering at Chalmers University of Technology with an interest in automotive engineering and traffic safety. They were required to possess a driving license for cars and have some years of experience from driving, preferably in Sweden or countries with comparable traffic environment.

Training of the annotators included an introduction to the euroFOT project and to traffic safety and FOTs, guidance for understanding the concepts of accident models, active and passive safety, and for understanding the challenge in analysing FOT data and the relationship between accidents and incidents. During individual coding, the supervisor took part of the development, guiding the annotators in difficult cases.
Annex 9: List of abbreviations

ACC  Adaptive Cruise Control
FCW  Frontal Collision Warning
LDW  Lane Departure Warning
IW   Impairment Warning
BLIS Blind Spot Information
SL   Speed Limiter
CC   Cruise Control
SRS  Speed Regulation System (CC+SL)
FEA  Fuel Efficiency Advisor
CSW  Curve Speed Warning
PI   Performance Indicator
OR   Odds ratio
CBA  Cost Benefit Analysis
THW  Time headway
MM   Man Month
NHTSA National Highway Traffic Safety Administration
ACAT Advanced Crash Avoidance Technologies
GCW  Gross Combination Weight
Annex 10: Overview of safety-related measures

<table>
<thead>
<tr>
<th>THW (time headway)</th>
<th>Signal from sensor.</th>
</tr>
</thead>
<tbody>
<tr>
<td>TTC (Time to Collision)</td>
<td>Distance to the lead vehicle divided by relative speed.</td>
</tr>
<tr>
<td>TLC (Time to Lane Crossing)</td>
<td>Distance to the lane marking divided by the lateral speed of the vehicle. Vehicle size and angle is taken into account as far as possible.</td>
</tr>
</tbody>
</table>

- **Critical time headway (THW)**
  1. Number of THW events below 0.5 seconds.
  2. Percentage of THW below 0.5 seconds.

- **Critical TTC**
  Percentage of time with TTC < 1.75 seconds; base is time in car follow situation.

- **Critical TLC**
  Percentage of time with TLC < 1 second; base is time with stable lane tracking

- **Harsh braking event**
  1. **Strong braking reaction trucks**: defined as brake pedal speed > 100%/s (positive value means depression) combined with vehicle speed > 50km/h and longitudinal acceleration <= -2m/s² within +/- 3 seconds around the end of the braking event.
  2. **Strong braking reaction cars**: defined as second time derivative of the brake pressure higher than a certain threshold (9.0 bar/s²) and minimal longitudinal deceleration (-1m/s²) reached within 1sec. and the speed at the moment of the jerk is ABOVE defined threshold (10km/h).
  3. **High decelerations (cars)**: High deceleration is a deceleration below a speed-depend threshold $a_v$:
    - $v \leq 50$: $a_v = -6m/s^2$
    - $50 < v \leq 150$: $a_v = -6m/s^2 + 2m/s^2(v - 50km/h)/(150km/h - 50km/h)$
    - $v > 150$: $a_v = -4m/s^2$
  4. **High decelerations (trucks)**: High deceleration is a deceleration below a speed-depend threshold $a_v$:
| Strong jerk event | v≤50: \( a_x = -5.4 \text{m/s}^2 \)  
| v>50: \( a_x = -5.4 \text{m/s}^2 + 1.8 \text{m/s}^2 \frac{(v - 50 \text{km/h})}{150 \text{km/h} - 50 \text{km/h}} \) |
| Strong jerk events are events with jerk (time derivative of longitudinal acceleration) below \(-2 \text{m/s}^3\) coupled with a longitudinal acceleration below \(-2 \text{m/s}^2\). The minimal duration of a strong jerk event is 0.2 seconds. |
| Lane exceedance | Wheel over lane marking; exceedance are only taken into account when lane marking is continuous; frequency per hour driving while lane tracking is stable has been calculated. |
| Incident | 1. **Kinematic incidents**: based on vehicle dynamics compared to pre-defined thresholds see (Benmimoun, M. et al., 2011) for detailed implementation.  
| | 2. **Video annotated incidents**: video annotation of pre-selected events detected using comparatively low kinematic thresholds. Annotated events are classified between frontal and lateral. See Annex 1: Video annotation in euroFOT for detailed annotation scheme. |
| MLO | Median lateral offset from the middle lane |
| MSW | Mean steering wheel angle |
| SYR | Standard deviation of yaw rate |
| Secondary task | Video-based annotation during both normal driving and crash relevant events. Classified into:  
| | 1. Use of nomadic device;  
| | 2. Manual (e.g., reaching for objects in vehicle);  
| | 3. Visual (e.g., looking at passengers/looking for objects in the car);  
| | 4. Cognitive (e.g., talking/listening to passenger);  
| | 5. No secondary task;  
| | 6. Unknown. |
| Focus on forward roadway | Video-based annotation during crash relevant events only. This variable indicates whether “not looking ahead” caused the event. |