## TeleFOT applications efficiency impact

<table>
<thead>
<tr>
<th>Report Summary</th>
<th>TeleFOT applications efficiency impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sub Project</td>
<td>SP 4</td>
</tr>
<tr>
<td>Workpackage</td>
<td>WP 4.5</td>
</tr>
<tr>
<td>Task</td>
<td>T 4.5.1-3</td>
</tr>
<tr>
<td>Authors</td>
<td>Touliou, K. (CERTH/HIT); Brignolo, R. (CRF); Innamaa, S., Rämä, A. (VTT); Pagle, K. (ICCS); Will, D. (IKA)</td>
</tr>
<tr>
<td>File name</td>
<td>TeleFOT_D 4 5 3_TeleFOT applications - Efficiency impact_v3.1.doc</td>
</tr>
<tr>
<td>Status</td>
<td>Final</td>
</tr>
<tr>
<td>Distribution</td>
<td>Public (PU)</td>
</tr>
<tr>
<td>Issue date</td>
<td>2012-10-15</td>
</tr>
<tr>
<td>Creation date</td>
<td>2013-01-15</td>
</tr>
<tr>
<td>Project start and duration</td>
<td>1st of June, 2008 – 54 months</td>
</tr>
<tr>
<td>Project co-funded by the European Commission</td>
<td>DG-Information Society and Media in the 7th Framework Programme</td>
</tr>
</tbody>
</table>
# TABLE OF CONTENTS

LIST OF FIGURES ................................................................................................. 4  
LIST OF TABLES ................................................................................................. 6  
LIST OF ABBREVIATIONS ............................................................................... 7  
REVISION CHART AND HISTORY LOG ........................................................... 10  
EXECUTIVE SUMMARY ................................................................................. 11  

1. INTRODUCTION .................................................................................... 16  
   1.1. Rationale .......................................................................................... 17  
   1.2. Background .................................................................................... 18  
   1.3. Summary of earlier findings ............................................................ 19  

2. METHODS ............................................................................................ 23  
   2.1. Field Operational Tests (FOTs) ....................................................... 30  
      2.1.1. Large scale tests (LFOTs) ......................................................... 30  
      2.1.2. Detailed scale tests (DFOTs) .................................................... 31  
   2.2. Functions ..................................................................................... 32  
      2.2.1. In-vehicle functions tested ...................................................... 33  
   2.3. Participants in FOTs ...................................................................... 35  
   2.4. Test designs ............................................................................... 37  
   2.5. Data ............................................................................................ 38  
      2.5.1. Travel diaries ............................................................................. 38  
      2.5.2. Logged data .............................................................................. 38  
      2.5.3. Questionnaires ........................................................................... 39  
   2.6. Statistical analysis ....................................................................... 39  

3. IMPACTS ............................................................................................. 41  
   3.1. Journey Duration .......................................................................... 41  
      3.1.1. Method .................................................................................... 41  
      Anticipated effects of functions and their combinations ..................... 42  
      Statistical Testing .............................................................................. 43  
      3.1.2. Results .................................................................................... 43  
      Spread of data .................................................................................. 50  
      Correlation to Questionnaire data ..................................................... 52  
      Correlations to background variables .............................................. 53  
      Rush hour journeys ................................................................. 54  
      Daytime journeys ................................................................. 55  
      Night time journeys ............................................................... 55  
      Travel diary data analysis ............................................................. 56  
      3.1.3. Discussion and Conclusions ....................................................... 58  
   3.2. Perceived change in delays ............................................................... 60  
      3.2.1. Methods .................................................................................. 60  
      Anticipated effects of functions and their combinations ..................... 62  
      Statistical Testing .............................................................................. 62  
      3.2.2. Results .................................................................................... 62  
      3.2.3. Discussion and Conclusions ....................................................... 69  
   3.3. Speed variations and exceedances .................................................. 70  
      3.3.1. Methods .................................................................................. 70  

CERTH/HIT 2013/01/16

Page 2 of 133
3.3.2. Data analysis ........................................................................................................ 71
3.3.3. Discussion and Conclusions .......................................................................... 73

3.4. Car following behaviour ...................................................................................... 75
3.4.1. Methods ......................................................................................................... 75
3.4.2. Results ......................................................................................................... 76
Time headway (sec) .......................................................................................... 76
Space/distance headway (m) ........................................................................ 87
Methods .............................................................................................................. 87
3.4.3. Discussion and Conclusions .......................................................................... 91

3.5. Avoidance of traffic jams ................................................................................ 93
3.5.1. Methods ...................................................................................................... 93
3.5.2. Results ....................................................................................................... 94
Correlation to Background variables ............................................................... 98
3.5.3. Discussion and Conclusions ....................................................................... 102

4. IMPLICATIONS FOR EFFICIENCY .................................................................. 104
4.1. Navigation ....................................................................................................... 105
4.2. Traffic information ......................................................................................... 107
4.3. Speed limit information/alert ....................................................................... 109
4.4. Green driving support ................................................................................... 111
4.5. Focus groups with stakeholders ................................................................... 113
4.6. Societal impacts ............................................................................................. 114

5. SCALING UP TO EUROPEAN LEVEL ......................................................... 116

6. CONCLUSION ............................................................................................... 124

7. REFERENCES ............................................................................................... 126

ANNEX I – TESTED DEVICES ........................................................................ 129
ANNEX II – STATEMENT OF PRINCIPLES REGARDING DATA-SHARING
FOLLOWING TELEFOT ................................................................. 132
LIST OF FIGURES

Figure 1. TeleFOT efficiency model: Impacts on traffic efficiency and indicators. 26
Figure 2. Median scores for reported driving experience, style and km driven per year. ................................................................. 36
Figure 3. Driven km per year for female and male participants. ...................... 37
Figure 4. Impact of green driving application on duration of frequently made journeys in Finnish LFOT .................................................. 47
Figure 5. Impact of speed information/alert on duration of frequently made journeys in Finnish LFOT. ............................................. 48
Figure 6. Impact of navigation and speed information/alert on duration of frequently made journeys in Valladolid LFOT ..................................... 49
Figure 7. Impact of green driving, traffic information and navigation on duration of frequently made journeys in Swedish LFOT2 .................................. 49
Figure 8. Impact of navigation and traffic information application on duration of frequently made journeys in Greek LFOT3 ..................................... 49
Figure 9. Perceived change in encountered delays because of using the navigation support function. .............................................................. 63
Figure 10. Driven Km per year distribution per LFOT site ........................................ 64
Figure 11. Perceived driving experience distribution per LFOT site .................... 65
Figure 12. Type of roads per LFOT site .......................................................... 65
Figure 13. Perceived change in encountered delays because of using the traffic information function. ......................................................... 67
Figure 14. Distribution of reported km driven per year for LFOTs ....................... 68
Figure 15. Distribution of reported driving experience for LFOTs ............................ 68
Figure 16. Distribution of road types per LFOT .................................................. 69
Figure 17. Route 3 of German DFOT with speed limits ........................................ 72
Figure 18. Velocity profile without driver assistance system. .............................. 74
Figure 19. Velocity profile with ADAS (penetration rate: 20 %) .......................... 74
Figure 20. Mean time headway (sec) in the Greek DFOTs ................................ 77
Figure 21. Mean time headway (sec) in UKDFOT2 ........................................ 78
Figure 22. Mean time headway (sec) in German DFOT ...................................... 78
Figure 23. Mean standard deviation for time headway in Greek DFOTs .............. 79
Figure 24. Mean standard deviation of Time Headway in UKDFOT .................. 80
Figure 25. Mean standard deviation of Time Headway in German DFOT .......... 81
Figure 26. Mean minimum time headway in Greek DFOTs ............................... 82
Figure 27. Time headway distribution for the whole route in Greek DFOTs ........ 84
Figure 28. Percentage of time spent with time headway<1.5 sec in the UKDFOT2 .......................... 84
Figure 29. Time headway distribution for the whole route in UKDFOT2 ............. 85
Figure 30. Time headway distribution for values less than five seconds in German DFOT ......................................................................... 86
Figure 31. Mean distance headway (m) in Greek DFOTs .................................... 88
Figure 32. Mean standard deviation distance headway (m) in Greek DFOTs .......... 89
Figure 33. Mean minimum distance headway in Greek DFOTs .......................... 90
Figure 34. Perception of change in traffic jams avoidance (Sweden; LFOT2) .... 95
Figure 35. Perception of change in traffic jams avoidance (Swedish LFOT4) ....... 96
Figure 36. Perception of change in traffic jams avoidance (Finnish LFOT) ........ 96
Figure 37. Perception of change in traffic jams avoidance (Spanish LFOT2) ...... 97
Figure 38. Perception of change in traffic jams avoidance (Greek LFOT3) ......... 97
Figure 39. Perception of change in traffic jams avoidance for all LFOTs .......... 103
Figure 40. FESTA recommendations for implications for impact areas ............ 104
Figure 41. Implications of navigation support for efficiency (positive impacts are highlighted with blue) ................................................................. 106
Figure 42. Implications of traffic information for efficiency (positive impacts are highlighted with blue) ............................................................... 108
Figure 43. Implications of speed limit/alert for efficiency (positive impacts are highlighted with blue) ............................................................. 110
Figure 44. Implications of green driving support for efficiency (slightly positive impacts are highlighted with lighter blue, negative with red, and conflicting with grey) ................................................................. 112
Figure 45. The possibilities for 100% scaling up the decrease in journey duration because of bundle of functions (navigation support and traffic information) ........................................................................ 119
LIST OF TABLES

Table 1. Important deliverables and objectives across SPs.............................. 23
Table 2. Data scripting per Efficiency Research Question ................................ 28
Table 3. Summary table for number of participants and km driven per LFOT included ........................................................................................................ 31
Table 4. Summary table for number of participants and km driven per DFOT included ........................................................................................................ 32
Table 5. Distribution of functions across FOT sites ........................................ 35
Table 6. Mean age (years) for female and male participants .............................. 36
Table 7. LFOT logged data specifics for journey duration ................................. 42
Table 8. Mean duration between comparable origins and destinations in baseline and treatment phase (t, p values included) ........................................ 45
Table 9. Proportion of OD pairs with difference in duration .............................. 50
Table 10. Direction change for journey duration in questionnaire and logger data .............................................................................................................. 53
Table 11. Average duration of commuting journey when a certain function was in use or no function was in use (treatment period travel diaries) and average duration of the commuting journeys of the same participants in baseline period (1st travel diary) with no function in use (baseline/treatment, min), sample size at least 10 observations, statistically significant differences bolded .............................................................................................................. 58
Table 12. Data sources and functions tested for perceived change in delays .... 61
Table 13. Chi-square test results between change in traffic jams avoidance and total annual kilometers ................................................................. 98
Table 14. Chi-square test results between change in traffic jams avoidance and road types driven ..................................................................................... 99
Table 15. Chi-square test results between change in traffic jams avoidance and previous familiarity with function ................................................................. 100
Table 16. Chi-square test results between change in traffic jams avoidance and previous access to function ................................................................. 100
Table 17. Chi-square test results between change in traffic jams avoidance and opinion 1 ................................................................................................. 101
Table 18. Chi-square test results between change in traffic jams avoidance and opinion 2 ................................................................................................. 101
Table 19. Chi-square test results between change in traffic jams avoidance and opinion 3 ................................................................................................. 102
# LIST OF ABBREVIATIONS

<table>
<thead>
<tr>
<th>ABBREVIATION</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACC</td>
<td>Adaptive Cruise Control</td>
</tr>
<tr>
<td>ADAS</td>
<td>Advanced Driver Assistance System</td>
</tr>
<tr>
<td>ANOVA</td>
<td>Analysis of Variance</td>
</tr>
<tr>
<td>CACC</td>
<td>Cooperative Adaptive Cruise Control</td>
</tr>
<tr>
<td>CAN</td>
<td>Controller-Area Network</td>
</tr>
<tr>
<td>CAS</td>
<td>Collision Avoidance System</td>
</tr>
<tr>
<td>DFOT</td>
<td>Detailed Field Operational Test</td>
</tr>
<tr>
<td>D-GPS</td>
<td>Differential Global Positioning System</td>
</tr>
<tr>
<td>DTC</td>
<td>Distance-to-Collision</td>
</tr>
<tr>
<td>EFF</td>
<td>Efficiency</td>
</tr>
<tr>
<td>ETA</td>
<td>Effective Time of Arrival</td>
</tr>
<tr>
<td>FCW</td>
<td>Forward Collision Warning</td>
</tr>
<tr>
<td>GDS</td>
<td>Green Driving Support</td>
</tr>
<tr>
<td>GPS</td>
<td>Global Positioning System</td>
</tr>
<tr>
<td>NSD</td>
<td>Navigation Support (Dynamic)</td>
</tr>
<tr>
<td>NSS</td>
<td>Navigation Support (Static)</td>
</tr>
<tr>
<td>ICT</td>
<td>Information Communication Technologies</td>
</tr>
<tr>
<td>IRS</td>
<td>Route Information Sharing</td>
</tr>
<tr>
<td>ISA</td>
<td>Intelligent Speed Adaptation</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
</tr>
<tr>
<td>--------------</td>
<td>-------------</td>
</tr>
<tr>
<td>ITS</td>
<td>Intelligent Transport System</td>
</tr>
<tr>
<td>IVIS</td>
<td>In-Vehicle Information System</td>
</tr>
<tr>
<td>HD</td>
<td>High Definition</td>
</tr>
<tr>
<td>LDW</td>
<td>Lane Departure Warning</td>
</tr>
<tr>
<td>LFOT</td>
<td>Large Scale Field Operational Test</td>
</tr>
<tr>
<td>LKA</td>
<td>Lane Keep Assistance</td>
</tr>
<tr>
<td>NAV</td>
<td>Navigation</td>
</tr>
<tr>
<td>OBDII</td>
<td>On Board Diagnostic System</td>
</tr>
<tr>
<td>OD</td>
<td>Origin-Destination</td>
</tr>
<tr>
<td>PELOPS</td>
<td>Program for the dEvelopment of Longitudinal micrOscopic traffic Processes in a Systemrelevant environment</td>
</tr>
<tr>
<td>PND</td>
<td>Portable Navigation Device</td>
</tr>
<tr>
<td>POIs</td>
<td>Points of Interest</td>
</tr>
<tr>
<td>RDS</td>
<td>Radio Data system</td>
</tr>
<tr>
<td>RQ</td>
<td>Research Question</td>
</tr>
<tr>
<td>SA</td>
<td>Speed Alert</td>
</tr>
<tr>
<td>SD</td>
<td>Standard Deviation</td>
</tr>
<tr>
<td>SLI</td>
<td>Speed Limit Information</td>
</tr>
<tr>
<td>SI</td>
<td>Speed Information</td>
</tr>
<tr>
<td>TD</td>
<td>Travel Diaries</td>
</tr>
<tr>
<td>THWY</td>
<td>Time Headway</td>
</tr>
<tr>
<td>TeleFOT applications efficiency impact</td>
<td>PU</td>
</tr>
<tr>
<td>---------------------------------------</td>
<td>----</td>
</tr>
<tr>
<td>Copyright TeleFOT</td>
<td></td>
</tr>
<tr>
<td>Contract N 224067</td>
<td></td>
</tr>
<tr>
<td>TI</td>
<td>Traffic Information</td>
</tr>
<tr>
<td>TLC</td>
<td>Time-to-Line-Crossing</td>
</tr>
<tr>
<td>TTC</td>
<td>Time To Collision</td>
</tr>
<tr>
<td>2G/3G</td>
<td>2\textsuperscript{nd} Generation/3\textsuperscript{rd} Generation</td>
</tr>
</tbody>
</table>
## REVISION CHART AND HISTORY LOG

<table>
<thead>
<tr>
<th>REV</th>
<th>DATE</th>
<th>REASON</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2012/11/10</td>
<td>Contribution by all partners received</td>
</tr>
<tr>
<td>1.1</td>
<td>2012/11/12</td>
<td>Contributions incorporated</td>
</tr>
<tr>
<td>1.2</td>
<td>2012/11/20</td>
<td>First draft ready for review</td>
</tr>
<tr>
<td>2</td>
<td>2012/12/21</td>
<td>Second draft ready for peer review among contributing partners</td>
</tr>
<tr>
<td>2</td>
<td>2013/01/10</td>
<td>Second draft sent for internal peer review</td>
</tr>
<tr>
<td>2.1</td>
<td>2013/01/09</td>
<td>Comments received by TeleFOT partners</td>
</tr>
<tr>
<td>2.2</td>
<td>2013/01/15</td>
<td>Comments received by internal peer review</td>
</tr>
<tr>
<td>3</td>
<td>2013/01/15</td>
<td>Changes implemented based on received feedback</td>
</tr>
<tr>
<td>3.1</td>
<td>2013/01/15</td>
<td>Final version submitted to EC</td>
</tr>
</tbody>
</table>
EXECUTIVE SUMMARY

This deliverable presents the efficiency impact assessment results in TeleFOT by providing summaries of main findings in relation to respective research questions. Implications of TeleFOT functions to efficiency were assessed and conclusions were drawn based on both findings and implications.

This deliverable describes the impacts of nomadic devices on traffic and driver efficiency. The following functions were selected for TeleFOT project to investigate if they have a direct or indirect effect on traffic and driver efficiency.

- Navigation support
- Speed information/Speed alert
- Traffic information
- Green driving support

The implementation of large scale tests with emphasis on the driver by measuring the impact of existing devices with TeleFOT functions fills in an existing gap in European research.

Increasing traffic efficiency is a goal aimed at harmonised traffic flow, optimal traffic volume, increased road capacity, fewer accidents, and greater accessibility for all involved road users. Consideration in TeleFOT is made solely for passenger cars and not other involved road users that are affecting traffic elements (e.g. modal choice or change).

Analysis was based on the TeleFOT efficiency model which included several measurable efficiency indicators.

The following research questions were addressed (relevant sub-section in brackets):

| EFFRQ1. Is the travel time from origin to destination affected? (3.1) |
| EFFRQ2. Are there any delays avoided (3.2) |
| EFFRQ3. Are the vehicles’ speeds in the network increased/decreased? (3.3) |
| EFFRQ4. Is the time headway between the vehicles increased/decreased? (3.4) |
| EFFRQ5. Are there any traffic jams avoided? (3.5) |
| EFFRQ6. Is the distance from the preceding vehicle smaller/larger? (3.6) |
The use of a bundle of functions with traffic information, green driving and navigation support seems to significantly decrease journey duration (10%) when compared to baseline without any functions (Swedish LFOT 2). On the other hand, green driving increases journey duration (13.1%) when compared to using traffic information and speed information/alert as baseline functions. Speed exceedances were not affected by the use of the bundle of functions.

Significant decrease in headway variations were found in Greek and UK DFOTs because of using a combination of ADAS and functions. In addition, users in both DFOTs were found to spent considerable less time (almost half less) with dangerously small headways (<1 second) when compared to baseline conditions.

Participants that used the traffic information function reported slight decrease in encountered delays and traffic jams (LFOTs). Variations in answers across LFOT sites were large (range 10%-45% for both delays and traffic jams) for significance to be revealed. Drivers in larger cities with congestion problems (e.g. Athens) reported decrease in encountered delays and traffic jams. There appears to be a relationship between “exposure” and “sensitivity to change”. For example, living in a highly congested city means that drivers probably need and use more the traffic information system and probably report that the system helped them more to avoid delays and traffic jams.

Speed information and alert appear to play secondary role for efficiency. As anticipated, traffic information is the key function (primary) for efficiency. Green driving support has a negative impact for journey duration but appears to be positive for headway distribution (e.g. distribution of small and dangerous headways); therefore, its role appears to be conflicting.

The following tables present the main outcomes per function tested with efficiency impact assessment area.

**Navigation**

<table>
<thead>
<tr>
<th>Journey duration</th>
<th>Decrease in duration of comparable origin / destination journeys with function use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perceived change in delays</td>
<td>No significant change with function use</td>
</tr>
<tr>
<td>Perceived avoidance of traffic jams</td>
<td>No significant change with function use</td>
</tr>
</tbody>
</table>

CERTH/HIT
### TeleFOT applications - Efficiency Impact

<table>
<thead>
<tr>
<th>Speed variations and exceedances</th>
<th>No significant change with function use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car following behaviour</td>
<td>Significant decrease in time spent with very low headway values (when bundled with ADAS)</td>
</tr>
<tr>
<td></td>
<td>Significant decrease in headway variations</td>
</tr>
</tbody>
</table>

### Traffic Information

<table>
<thead>
<tr>
<th>Journey duration</th>
<th>Decrease in duration of comparable origin / destination journeys with function use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perceived change in delays</td>
<td>No significant avoidance with function use</td>
</tr>
<tr>
<td>Perceived avoidance of traffic jams</td>
<td>No significant change with function use</td>
</tr>
<tr>
<td>Speed variations and exceedances</td>
<td>No significant change with function use</td>
</tr>
<tr>
<td>Car following behaviour</td>
<td>Significant decrease in time spent with very low headway values (when bundled with ADAS)</td>
</tr>
<tr>
<td></td>
<td>Significant decrease in headway variations</td>
</tr>
</tbody>
</table>

### Speed limit information / speed alert

<table>
<thead>
<tr>
<th>Journey duration</th>
<th>No significant change with function use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perceived change in delays</td>
<td>No significant change with function use</td>
</tr>
<tr>
<td>Perceived avoidance of traffic jams</td>
<td>No significant change with function use</td>
</tr>
</tbody>
</table>
Speed variations and exceedances | No significant change with function use
---|---
Car following behaviour | Significant decrease in time spent with very low headway values (when bundled with ADAS)
| Significant decrease in headway variations

**Green Driving**

<table>
<thead>
<tr>
<th>Journey duration</th>
<th>Increase in duration of comparable origin / destination journeys with function use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perceived change in delays</td>
<td>No anticipated effect</td>
</tr>
<tr>
<td>Perceived avoidance of traffic jams</td>
<td>No anticipated effect</td>
</tr>
<tr>
<td>Speed variations and exceedances</td>
<td>No significant change with function use</td>
</tr>
</tbody>
</table>
| Car following behaviour | Significant decrease in time spent with very low headway values (when bundled with ADAS)
| Significant decrease in headway variations |

Scaling up was based mainly on European statistical data (EU Transport in figures, Statistical Pocketbook, 2012) for two statistically significant findings. Scaling up was performed for three penetration rates (20%, 50%, 100%). If passenger cars in Europe were equipped with navigation support and traffic information, then the duration of journeys could be decreased by 359 million (range: 253-465 million) hours per year and 6.3 billion (range: 5-8 billion) hours per year (for 20% and 100% penetration rates, respectively). Likewise, if passenger cars were equipped with ADAS and any of the TeleFOT functions, drivers in Europe could spend between 1528 hours and 7609 fewer hours with dangerously small headways per 1000 people (for 20% and 100% penetration rates, respectively).
The impact of these functions is indirect because it is probably positive for the stability of the traffic, specifically, string flow (i.e. because of car following) rather than directly enhancing efficiency by increasing flow or increasing volume and capacity. The decrease in variation for mean headway in DFOTs when any of the functions were used with ADAS -when compared to baseline alone- was found to be also positive for the stability of traffic flow. The effect is not clear if it could be attributed only to ADAS or only to functions but their effect is nonetheless complementary and not contradictory.

It is difficult to predict what the situation for these functions will be in the next five years due to the current economical situation in Europe. The effect of increasing unemployment rates, decrease in registration of new vehicles (a decrease of 1.2% in registration of new vehicles was recorded between 2009 and 2010), and increase in fuel prices will probably have an impact on the penetration of nomadic devices and the deployment of new functions in the European market. Additionally, it is not clear if the impact of these factors will be counterbalanced by the exponential growth in technology innovations and sales for nomadic devices.

The findings and data from TeleFOT project could be the basis for creating European databases in collaboration with other related projects (e.g. EuroFOT) for both ADAS and functions. Such an effort requires both creating methodologies for harmonising the data and also close collaboration with the European statistical office for maintaining and assessing the harmonising process in order to follow an acceptable procedure according to standards set for centralised data processing.
1. INTRODUCTION

TeleFOT was a Large Scale Collaborative Project under the Seventh Framework Programme, co-funded by the European Commission DG Information Society and Media within the strategic objective "ICT for Cooperative Systems".

Officially started on June 1st 2008, TeleFOT aimed to test the impacts of driver support functions on the driving task with large fleets of test drivers in real-life driving conditions.

In particular, TeleFOT assessed via Field operational Tests the impacts of functions provided by aftermarket and nomadic devices, including future interactive traffic services that will become part of driving environment systems within the next five years.

Field Operational Tests developed in TeleFOT aimed at a comprehensive assessment of the efficiency, quality, robustness and user acceptance of in-vehicle systems, such as ICT, for smarter, safer and cleaner driving.

The analysis undertaken within the TeleFOT project aimed to assess the impact of aftermarket nomadic devices in five distinct assessment areas; Safety, Mobility, Efficiency, Environment and User Uptake. In order to measure the impacts SP2, in collaboration with SP4, developed core research questions and hypotheses for each assessment area that also took into account the functionality of the devices specifically under consideration in TeleFOT.

This deliverable describes the impacts of nomadic devices on traffic and driver efficiency. The following functions were selected for the TeleFOT project to investigate whether they have a direct or indirect effect on traffic and driver efficiency.

- Navigation support
- Speed information/Speed alert
- Traffic information
- Green driving support

In particular, this deliverable presents the efficiency impact assessment results in TeleFOT by providing summaries of main findings for specific research questions. Implications of TeleFOT functions to efficiency were assessed and conclusions were drawn based on both findings and implications.
This chapter presents the objectives for the efficiency impact assessment area, relevant studies, and the objectives and purposes of the studies.

1.1. Rationale

Contemporary driving behaviour models have moved beyond the paradigm shift that occurred during the 1970s. Automaticity is a well-established term in current research as individual differences are also for research paradigms. Drivers are not merely addressed by “input-output” theories but their personal characteristics and idiosyncrasies have come into play. Therefore, from automaticity research focus was shifted to human factors and the role of the individual in research. Naturalistic observations were the first steps in scientific research towards realistic data gathering.

Since then, great focus has been placed on errors and accidents in driving research in order to make roads “safer” for drivers in Europe and the whole world. Nowadays, moving forward from accident causation, driving behaviour has been considered within a broader context of transportation for many reasons (e.g. going from home to work, or going from home to the super market). Large scale efforts in transport can accommodate for broadening the exploration of driving variables in these different daily occasions.

In order to delineate future research, it is important to go beyond accidents. Driving is not only the study of accidents, near-misses, and cognitive errors but also the study of driving behaviour in order to make it more efficient for the driver and the traffic network. It is easy to see that decreasing accidents and eliminating errors would result in a more harmonious and, therefore, more efficient road networks.

One direction for paving the way for future research is by modifying existing designs or creating new methodologies. Methodologies enable models to be empirically tested and therefore to be taken seriously in the research arena. New methodologies focusing on individual driving performance in realistic settings are used in order to test existing and developing in-vehicle systems for some time now.

The most important factor in developing assisting systems is the driver, hence if the driver is not willing to use these systems they will not be able to be used and, therefore, they will not contribute to existing transport systems. The inclusion of
aftermarket nomadic devices solves the problem of willingness to use as they already exist in the market. As the driver has to use these devices in order for changes in transport to happen, regardless if implemented or not by companies, the starting point should be the driver and their perspective.

Therefore the implementation of large scale and detailed tests, with emphasis on the driver, by measuring the impact of existing devices with TeleFOT functions (aftermarket and nomadic devices) fills in an existing gap in European research.

1.2. Background

Intelligent Transport Systems (ITS) are expected to benefit the whole transportation system till 2020 and objectives will actually be set in order to be met by all active members (from researchers to European operators) based on results by several EU projects. Additionally, advancements in quality of data collection methods and abundance of ICT solutions will change existing traffic and mobility models. In coming decades cooperative systems are anticipated to alter the status quo in transportation. It will not be too far in the future when highly sophisticated and complex systems will provide personalised support to drivers by providing both assistance and information and the distinction used today between informative and driving assistive systems will not apply and will be outdated.

Till then, the already accomplished advancements of Advanced Driver Assistance Systems (ADAS) and In-Vehicle Information Systems (IVIS) that emerged in the last decades have penetrated the vehicle market and created new possibilities. The different types of support to driver and vehicle are categorised to ADAS and IVIS for better communication of related findings. These systems’ priority is to enhance driver’s safety.

The increasing use of safety systems could lead to decrease in traffic efficiency and vice versa. Optimal traffic efficiency is characterised by harmonised traffic flow, optimal traffic volume, increased road capacity, fewer accidents, and greater accessibility for all involved road users. In TeleFOT, consideration is made solely for passenger cars and not other involved road users that are affecting traffic elements (e.g. actual weekly modal choice or change).

According to traffic engineering theory (Pline, 1992), speed increase could lead to higher network efficiency and decrease of vehicle headway could lead to more efficient traffic conditions with optimised distances between vehicles. If speeds in
the network and headways are adjusted, then road capacity could increase and delays and jams could be decreased (Golias et al., 2010).

It seems that there are two inferential poles (i.e. safety-efficiency) for data analysis. However, not all research should be directed towards this positive/negative relation between these two impact areas. For example, decrease in accidents, increases safety and at the same time increases traffic efficiency. Obviously, decrease in accidents means that less people are killed or injured on the road. If less accidents happen traffic flow suffers less disturbances and disruptions and the capacity of the road segment can be better used. (e.g. disruptions because of police vehicles and paramedics arriving at the specific location resulting in re-routing for a short period of time).

Hence, in order to say that the use of the system enhances traffic efficiency, then decreases of distances or increases of average speeds should be within safe limits for optimisation and harmonisation to be feasible. Thus, a road network should be both safe and efficient.

1.3. Summary of earlier findings

Mobility is an important aspect of everyday life. The advances in technology increase the use of devices and complex systems while driving. Increased mobility increases also the problems that are related to it. Increased mobility consequently increases accidents, congestions, delays, and decreases safety. It is estimated that congestion problems occur daily on 10% of major road networks in Europe and the associated costs are estimated to be 50 billion Euros per year in addition to 200 billion Euros safety related accidents costs (European Commission, 2010). In addition, human errors such as misconceptions, drivers’ lowered reaction times, little anticipative beaviour and increased gaps are important threats for destabilising the traffic flow and creating congestions.

There have been high expectations about in-vehicle and driving assistance systems for contributing in solving the aforementioned problems. Many studies have focused on the impact of using in-vehicle systems with simulators and simulation models in order to identify their effect on traffic. In order to meet the expectations for these systems to be safely used in traffic, on road studies are necessary to be conducted in order to provide insight to the potential effects and impacts on the driver and traffic efficiency.
Studies presented are categorised in driving support systems/functions (e.g. navigation support, traffic information, speed information) and vehicle support systems/functions (collision avoidance system, lane departure system, speed control, speed alerts, Adaptive Cruise Control) (Golias et al., 2001). The adoption of this distinction is merely applied for the purposes of this analysis. The main reason for presenting current findings on both system types is that in some DFOTs the functions were tested in conjunction with ADAS.

This section includes a brief literature overview of studies relevant to the FOTs conducted within TeleFOT project.

World car navigation market is growing continuously and is expected to reach 16.32 million sets in 2015 (Yano Research Institute, 2011). Increasingly more drivers are using dynamic navigation systems with information about potential delays and congestion. Yamashita and colleagues (2004) found that when drivers received accumulated traffic information with a Route Information Sharing (IRS) system, travel time decreased. If the system usage increased, then travel time decreased even more. Their findings were based on multiagent simulation.

Several simulation studies have investigated the potential impact of Adaptive Cruise Control (ACC) on traffic flow. Van Arem and colleagues (2006) examined the traffic flow effects of Cooperative Adaptive Cruise Control (CACC). This ACC system exchanges information with the vehicle ahead, so that it can follow this vehicle more closely. The results indicated an improvement of traffic flow stability because of smaller standard deviations of speed and a slight increase of traffic efficiency indicated by higher queue discharge flows. The use of ACC systems could contribute to reducing head-tail accidents, but it could also reduce the traffic throughput, depending on the system settings (Minderhoud, 1999). A combination of ACC and Lane Departure Warning (LDW) was tested in the Alkim, Bootsma & Looman (2007) study. ACC was found to be more effective than LDW and slight increase in the variation of lateral position in the lane was found indicating a positive integration effect for some of the test drivers. Participants stated that the warning issued by LDW increased their alertness. With a 40% ACC equipment rate and one second headway time, Broqua and colleagues (1991) estimated throughput gains at 13%. Van Arem and colleagues (1996) and Minderhoud & Bovy (1999) found a decrease in average speed when ACC with headway times of 1.4 seconds and above were used. Minderhoud & Bovy (1999) performed simulations with headway times as low as 0.8 seconds and concluded
that current ACC using a one second headway time could achieve capacity gains of 4%. However, very low headway values could result in capacity gains as it was shown with micro-simulation but the safety implications could reduce these gains. Therefore, in TeleFOT a positive result for efficiency had to be also within safe limits (e.g. decrease in headways but within safe limits).

Another very promising type of advanced driver support system is Intelligent Speed Adaptation (ISA). ISA could affect traffic efficiency by decreasing the homogenisation of driving speeds. The results of micro-simulation modelling showed that in high traffic density conditions, ISA would not have a significant effect on network total travel time because driving speeds are already largely limited by congestion in high traffic density conditions. However, in lower traffic density conditions, the travel time would increase due to lower average speeds, especially with increasing ISA penetration rates. (Liu et al., 1999).

These studies showed that different systems could have a positive effect on efficiency and potentially they could be used as an integrated set of functions. This is an important aspect for assessing the effect of adding different functions or using different systems in a vehicle. The capacity for control (e.g. in-vehicle multi-tasking) for both vehicle (engineering/design aspect) and driver (human factor aspect) remains undetermined as the combinations are different for each study and a meta-analysis at this level is difficult to be carried out.

Additionally, as shown above usually simulation studies are used for evaluating the effect of different systems on traffic efficiency. These models use different algorithms- for instance, for calculating different headway times- and apply them in diverse environments, at several penetration rates using various behavioural models. Moreover, different models and software packages are used for carrying out simulations. All these differences strongly influence the outcomes on traffic aspects such as capacity and speed, and therefore, make it very difficult to compare these studies and their results. The real element is important for

Communication between vehicles and between vehicle and roadside is considered the technology that will make a whole new generation of ITS functions possible. Several European research projects such as SAFESPOT (www.safespot-eu.org/), COOPERS (http://www.coopers-ip.eu/) and CVIS (www.cvisproject.org/) are worked on cooperative systems. Cooperative ACC (CACC) involves communication among successive vehicles (ACC-equipped) in the same lane and communication with roadside systems. The vehicles exchange information on
their position, speed and deceleration (De Bruin et al., 2004). This may increase safety and traffic efficiency as the ACC system can optimise its speed support and drivers can get early warnings of braking or of slow vehicles ahead. The potential road safety benefit may be accompanied by a better performance on traffic throughput and emissions on main roads (Malone & Van Arem, 2004). For instance, CACC with 0.5 seconds headway time would almost enable doubling of the traffic flow at 100% penetration rate (Van der Werf et al., 2002). As tasks are becoming even more automatic and more efficiently integrated into other systems, then their usage will be even safer and the effect to throughput might increase.

According to an IVIS study carried out in both simulated and real environments by Santos and colleagues (2004), as soon as participants in both road contexts realised that they could not handle both tasks (vehicle control and IVIS-related secondary task) they changed their behaviour (adjusted control). The adoption of lower (i.e., safer) speed, smaller distance to the road shoulder, and a longer margin towards vehicles in front was particularly clear in the simulator and field. Therefore, drivers do adjust control when they realise there is a problem. This is important also in cases of conflicting messages from different devices within the vehicle, as the driver has to prioritise them.

Despite the increasing amount of knowledge on driver support and in-vehicle systems, it can be concluded that there are no simple, straightforward assumptions on how these systems will influence driving behaviour and traffic flow performance. Many effects are still unknown and more research is required (Van der Heijden & Marchau, 2005).
2. METHODS

This chapter outlines the methodological approaches adopted in TeleFOT LFOT and DFOT sites with regards to Efficiency. The work builds on the existing methodology framework accomplished in the FESTA project -and documented in the FESTA Handbook - following a modified and more elaborate process. Both top-down (i.e. based on an underlying theoretical framework) and bottom-up (i.e. based on the different functions to be tested, use cases etc.) procedures were used for generating research questions and hypotheses which were then applied in TeleFOT FOTs and could be applied in all types of future FOTs.

Some of the research questions have been investigated in previous research efforts but TeleFOT is the first major longitudinal multi-centred study which has applied these research questions using an FOT methodology. Data not only from different sources but also from different sites were analysed in order to answer specific research questions.

A detailed account of the overall strategy developed within TeleFOT can be found in Deliverable D2.2.1, Testing and Evaluation Strategy.

The work presented in this Deliverable resulted by the interaction and close collaboration of SP2, SP3, and SP4. The main deliverables connected to the work presented within this document and their objectives are presented in the following table. The list is not exhaustive as the level of complexity for the connections among partners was high in order to develop appropriate methods and achieve efficient data collection, storage and analysis (Table 1).

Table 1. Important deliverables and objectives across SPs

<table>
<thead>
<tr>
<th>SP</th>
<th>Deliverable(s)</th>
<th>Main objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP2 FOT Framework</td>
<td>D2.2.1 <em>Testing and evaluation strategy</em> (Karlsson et al., 2009)</td>
<td>TeleFOT adapted version of the FESTA general handbook for FOTs, where the needs of the TeleFOT test communities and the functions/systems were studied and taken into account</td>
</tr>
<tr>
<td></td>
<td>D2.3.1 <em>Data specification and quality</em> (Welsh et al., 2010)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>D2.5.1 <em>Functions specification</em> (Franzén et al., 2010)</td>
<td></td>
</tr>
<tr>
<td>SP</td>
<td>Deliverable(s)</td>
<td>Main objective</td>
</tr>
<tr>
<td>----</td>
<td>-------------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>SP3 Field Operational Tests</td>
<td>3.2.2a,b Test tools (Koskinen et al., 2009; Pagle et al., 2010)</td>
<td>The main objective of TeleFOT SP3 was to design, develop and validate three Test Communities for FOTs (including both large scale and detailed trials), covering the North, the Central and the South Europe, for the assessment of the introduction of nomadic devices to the vehicle environment</td>
</tr>
<tr>
<td></td>
<td>3.4.1 Field Operation Test plans (Gaitanidou et al., 2010)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3.5.1 Large scale FOT execution (Pagle et al., 2012)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3.6.1 Detailed FOT execution (Koskinen et al., 2012)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3.7.1 Data and user management description (Vassama et al., 2009)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3.7.2 Data and user management (Heikkinen et al., 2010)</td>
<td></td>
</tr>
</tbody>
</table>

| SP4 Evaluation and Assessment | 4.4.1 Tools for database handling-Software package and user guide (Koskinen et al., 2010) | Conduct data analysis to identify the implications of system use for efficiency (WP4.5). |
|                              | 4.5.1 Efficiency data analysis plan (Gaitanidou et al., 2010)                   |                                                                                           |
|                              | 4.5.2 Impacts to Efficiency-Preliminary results (Touliou et al., 2012)          |                                                                                           |

A detailed account of the efficiency impact assessment methodology is given in deliverable 4.5.1., *Efficiency data analysis plan*. The most important parts of the methodology were later refined in two stages (piloting and preliminary results) and discussed in deliverable 4.5.2.

The six areas of impact defined by FESTA are based on Draskóczy and colleagues (1998). Initially, developed for safety impact but it is applicable – to some extend- to efficiency. Certain aspects of traffic efficiency were selected that were represented by specific variables as depicted in Figure 1. Specifically, three aspects of traffic efficiency are considered within TeleFOT:

- Traffic flow (e.g. speed, travel time)
- Traffic volume
- Accessibility
Some indicators in model belong to more than one aspects. For example, time spent driving with lower headways is a headway indicator. The headway indicator belongs to two aspects (flow and volume) but driving time with low headway is assumed to affect flow more than volume. Any significant findings found for time spent with low headways would be inferred to has an impact on traffic flow according to the TeleFOT efficiency model depicted in Figure 1. Only significant findings were considered for determining the implications to efficiency (Chapter 4).

Efficiency is a complicated impact area and these three analysis directions were set. The first direction is the direct extrapolation of findings to the traffic network. In this case we get results from creating fleets for the traffic network. This is feasible also with the application of micro-simulation for calculating speeds in the network. Results from other research questions, though, are based on data collected from one or two research vehicles. Hence, the second indirect effect to traffic flow is the estimation of efficiency with focus on data analysis from actual testing with instrumented vehicles. Thirdly, the accessibility aspect of traffic efficiency is introduced as driver efficiency within this deliverable (i.e. subjective evaluation). Accessibility of the road network for the driver means avoidance of delays and traffic jams and is based on subjective assessments (i.e. User Uptake questionnaires).

Efficiency was viewed from the driver’s perspective. Simulation was expected to be performed for the research question focusing on speed variations and exceedances in the network (see Deliverable 4.5.1). It was anticipated that analysis will be based mainly on LFOTs and DFOTs findings and secondarily on simulation.

The three aspects were measured with specific variables (indicators). Overt impact was expected to be estimated by traffic micro-simulation for speed variations. Only DFOT data for answering RQ3 were initially planned to be used and simulated as traffic simulation models present limitations. Two reasons exist. First, the used tool (PELOPS) could accommodate for speed variations and not sufficiently for the other research questions. According to Sohn (2008) speed variations in different road segments and intersections are pretty important for traffic efficiency. Speed variations were planned to be simulated from the perspective of road user (within the framework of TeleFOT) and not infrastructure...
operatives. However, simulation was not conducted due to non significant results and, therefore, only covert impact was estimated by indicators.

Not all aspects of traffic efficiency were possible to be investigated within TeleFOT. Hence, research questions that could be answered were selected.

In addition, different impact assessment areas share research questions and overlapping between research questions and analysis is observed. Some research questions are mutually dependent as they could be viewed and, consequently, answered under the prism of more than one impact area. Specifically, longitudinal distances are important vehicle parameters for both safety and efficiency. Data analysis of speed and headway adjustments is related more to traffic efficiency impact assessment.

Figure 1. TeleFOT efficiency model: Impacts on traffic efficiency and indicators
The procedure followed for developing the methodology applied in efficiency impact area is presented in detail in the following table (Table 2). The scripting process involved several important steps; starting with finding the appropriate research questions and then connecting each research question with appropriate data sources, relevant functions to be tested, participants to be recruited and the respective variables to be measured and analysed. The initial and final steps of the scripting process are described in Deliverables 4.5.1 and 4.5.2.
<table>
<thead>
<tr>
<th>Research questions</th>
<th>Sources</th>
<th>Functions</th>
<th>Fleets</th>
<th>Design</th>
<th>Main variable(s)</th>
<th>Supporting variable(s)</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>EFF1</strong></td>
<td>Logged data</td>
<td>Primary: NAV(^{1})+TI(^{2})</td>
<td>Non-professional drivers</td>
<td>Pre-post</td>
<td>Travel time (duration)</td>
<td>Logged time and travel diaries</td>
<td>Driving Background variables’ stratification</td>
</tr>
<tr>
<td></td>
<td>User Uptake Questionnaires</td>
<td>Secondary: SA(^{3}) or SI(^{4})</td>
<td>Some professional drivers</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Travel diaries</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>EFF2</strong></td>
<td>User Uptake Questionnaires</td>
<td>Indirectly: NAV+TI</td>
<td>Non-professional drivers</td>
<td>Post only</td>
<td>Perceived avoidance of delays</td>
<td>User Uptake post questionnaires</td>
<td>Driving Background variables’ stratification</td>
</tr>
<tr>
<td><strong>EFF3</strong></td>
<td>DFOT data to be fed to micro simulation</td>
<td>SA, SI, GDS(^{5})</td>
<td>Non-professional drivers</td>
<td>Data taken from actual testing</td>
<td>Speeding behaviour</td>
<td>Longitudinal acceleration</td>
<td></td>
</tr>
</tbody>
</table>

1 NAV: Navigation support  
2 TI: Traffic Information  
3 SA: Speed Alert  
4 SI: Speed Limit information  
5 GDS: Green Driving support
<table>
<thead>
<tr>
<th>Research questions</th>
<th>Scripting elements</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reduced/increased?</strong></td>
<td>(PELOPS)</td>
</tr>
<tr>
<td><strong>RQ-EFF4</strong> Is the time headway between the vehicles increased/decreased?</td>
<td>DFOTs, Logged data</td>
</tr>
<tr>
<td></td>
<td>CAS(^6) with NAV, SI, SA, GD</td>
</tr>
<tr>
<td></td>
<td>Non-professional drivers</td>
</tr>
<tr>
<td></td>
<td>Time (THWY(^7) in sec)</td>
</tr>
<tr>
<td></td>
<td>Mean, min, max, variations</td>
</tr>
<tr>
<td></td>
<td>Distribution per road type categories</td>
</tr>
<tr>
<td><strong>RQ-EFF5</strong> Are there any traffic jams avoided?</td>
<td>User Uptake questionnaire</td>
</tr>
<tr>
<td></td>
<td>NAV, TI</td>
</tr>
<tr>
<td></td>
<td>Non-professional drivers</td>
</tr>
<tr>
<td></td>
<td>User Uptake (scale selection)</td>
</tr>
<tr>
<td></td>
<td>Distribution background questionnaire</td>
</tr>
<tr>
<td><strong>RQ-EFF6</strong> Is the distance from the preceding vehicle larger/smaller?</td>
<td>DFOTs, Logged data</td>
</tr>
<tr>
<td></td>
<td>CAS(^8) with NAV, SI, SA, GD</td>
</tr>
<tr>
<td></td>
<td>Non-professional drivers</td>
</tr>
<tr>
<td></td>
<td>Distance headway (DHWY(^9) in m)</td>
</tr>
<tr>
<td></td>
<td>Mean, min, max, variations</td>
</tr>
<tr>
<td></td>
<td>Distribution per speed category</td>
</tr>
</tbody>
</table>

---

\(^6\) CAS: Collision Avoidance System  
\(^7\) THWY: Time Headway  
\(^8\) CAS: Collision Avoidance System  
\(^9\) DHWY: Distance Headway
2.1. Field Operational Tests (FOTs)

Data from LFOTs and DFOTs were used for the analysis of efficiency research questions. The different FOTs were split into large and detailed FOTs and were implemented into eight different Test Sites across Europe. In order to coordinate all the activities in the different FOTs, TeleFOT has grouped the Test Sites into three different Test Communities:

- Northern Community
  - Finland
  - Sweden
- Central Community
  - France
  - Germany
  - UK
- Southern Community
  - Greece
  - Italy
  - Spain

The organisation of the different FOTs and Test Sites in communities facilitated both the coordination and management of all the activities of the project. The following subsections define the difference between large-scale and detailed FOTs within the framework of TeleFOT.

2.1.1. Large scale tests (LFOTs)

In large-scale tests, FOT drivers used their own vehicles in their daily travel. These vehicles were equipped with testing (aftermarket/nomadic) and recording devices which measured speed, position and in some cases acceleration and vehicle dynamics. For further details about the test communities and LFOTs execution, please refer to deliverables 3.2.2. Test communities’ description and 3.5.1 LFOTs execution.

Data from different LFOTs were used in order to answer efficiency related research questions (1, 2, and 5). The decision was based on the relevance of functions used with the research questions as described in deliverables 4.5.1 Efficiency data analysis plan and 4.5.2 Efficiency impact assessment-preliminary.
results. The following table provides a summary of data used from LFOTs for efficiency impact assessment.

Table 3. Summary table for number of participants and km driven per LFOT included

<table>
<thead>
<tr>
<th>FOT</th>
<th>Function / s</th>
<th>Data Type</th>
<th>Number of participants</th>
<th>Total driving km</th>
</tr>
</thead>
<tbody>
<tr>
<td>SWE-LFOT1</td>
<td>SA, GDS</td>
<td>Questionnaire</td>
<td>54</td>
<td>109,177</td>
</tr>
<tr>
<td>SWE-LFOT2</td>
<td>NAV, GDS, TI</td>
<td>Logger, Travel diary, Questionnaire</td>
<td>96</td>
<td>653,165</td>
</tr>
<tr>
<td>SWE-LFOT4</td>
<td>TI</td>
<td>Logger, Questionnaire</td>
<td>554</td>
<td>428,092</td>
</tr>
<tr>
<td>IT-LFOT</td>
<td>NAV, SI/SA</td>
<td>Logger, Travel diary, Questionnaire</td>
<td>168</td>
<td>4155133.254</td>
</tr>
<tr>
<td>ES-LFOT1</td>
<td>NAV, SI/SA</td>
<td>Logger, Travel diary, Questionnaire</td>
<td>120</td>
<td>4155133,254</td>
</tr>
<tr>
<td>ES-LFOT2</td>
<td>NAV, GDS</td>
<td>Logger</td>
<td>132</td>
<td>3,249,529</td>
</tr>
<tr>
<td>GR-LFOT 1-3</td>
<td>NAV, SI, TI, SA</td>
<td>Logger, Travel diary, Questionnaire</td>
<td>148</td>
<td>806,776</td>
</tr>
<tr>
<td>UK-LFOT</td>
<td>NAV, SI/SA</td>
<td>Logger, Travel diary, Questionnaire</td>
<td>80</td>
<td>Approx. 300,000</td>
</tr>
</tbody>
</table>

2.1.2. Detailed scale tests (DFOTs)

DFOTs were much more detailed in terms of behavioural parameters measured. During the detailed FOTs participants were using instrumented vehicles. Detailed FOTs generated in-depth data through detailed and sometimes repeated testing sessions over the FOT duration. Detailed testing provides a better possibility to give causal explanations to the differences between drivers than large-scale tests. Large-scale tests measure and record differences but can explain them only to some extent. Detailed descriptions of DFOTs executed within TeleFOT are
available in Deliverable D3.6.1 DFOTs execution. The following table provides a summary of data used from DFOTs for efficiency impact assessment.

Data were used from the following DFOTs:

- Greece, DFOT1, 2, 3
- Germany, DFOT
- UK, DFOT2

Table 4. Summary table for number of participants and km driven per DFOT included

<table>
<thead>
<tr>
<th>FOT</th>
<th>Function / s</th>
<th>Data Type</th>
<th>Number of participants</th>
<th>Total driving km</th>
</tr>
</thead>
<tbody>
<tr>
<td>UK-DFOT2</td>
<td>NAV, SI/SA, ACC, FCW, LKA</td>
<td>Logger</td>
<td>9</td>
<td>11400</td>
</tr>
<tr>
<td>GR-DFOT 1-3</td>
<td>NAV, SA, SI, FCW, LDW</td>
<td>Logger, Questionnaire</td>
<td>8</td>
<td>1305.6</td>
</tr>
</tbody>
</table>

2.2. Functions

The selection of LFOT and DFOT data was based on the relevance of the tested function or bundle of functions within each pilot site to both the impact assessment rationale and the efficiency research questions (Table 2). The main functions tested in TeleFOT can be found in both nomadic and aftermarket devices and are generically specified in D 2.5.1., as follows:

Traffic Information (TI)

The system provides drivers with real-time information about the status of the traffic system (this information may include congestions, weather conditions, road works, crashes, etc.). The system draws on external databases and links to a traffic control centre. It is designed to make the driver aware of the actual as well as potentially critical traffic conditions in the nearest road and street environment.
Speed Limit Information (SLI)

The driver is informed about the current speed of the vehicle and the current speed limit of the road/street used is also displayed. This function makes the driver aware of actual speed limits on the road/street used.

Speed Alert (SA)

Current speed of the vehicle and the current speed limit of the road/street are displayed and a warning is issued when speed limit is exceeded. It is designed to make the driver aware of actual speed limits on the road/street used and comply with current speed limit when the speed limit is exceeded (driver receives visual and/or auditory warning).

Navigation Support (Static) (NSS)

A NSS guides the user to a destination set beforehand through locating the vehicle (using a positioning system) and calculating "best path" (in terms of travel time, distance or other preferences) by the use of relevant algorithms. It is designed to provide navigation support to the driver to find the way towards a pre-defined destination.

Green Driving Support (GDS)

A system which calculates what environmental impact one or several of the actual conditions of choice of route, driving style, operation of driveline, etc. will have. The algorithm also calculates what measure the driver can take in order to improve the situation at hand. It is designed to provide driving support (on all driving task levels) to the driver (often in real time) in order to, if possible, reduce the actual environmental impact of the driving.

2.2.1. In-vehicle functions tested

In DFOTs instrumented vehicles were used that were equipped with in-vehicle functions. These functions are defined in 2.5.3 as follows:

Adaptive Cruise Control (ACC)

Adaptive Cruise Control supports the driver in selecting an appropriate speed and distance to the vehicle in front depending on his/her preferences and the current traffic situation. It controls actively the vehicle speed to adapt to drivers target speed and following distance. This function detects and tracks if a vehicle is in front and adjusts the speed accordingly (e.g. by controlling the throttle). If the
leading vehicle accelerates, the system follows up to the target speed whilst keeping the pre-selected following distance.

The function is intended to keep a preselected speed and following distance. It supports the driver at the operational level and was tested in German DFOT.

*Forward Collision Warning/Collision Avoidance System (FCW/CAS)*

A collision warning system provides alerts to assist drivers in avoiding or reducing the severity of crashes involving the equipped vehicle striking the rear of a leading vehicle. This function detects and tracks obstacles in front of the vehicle. In case the evaluation of trajectories and speed of the subject vehicle and the obstacle show a high probability of a collision, a warning is issued to the driver. The function is intended to decrease drivers reaction time in case of potential rear-end accidents. It supports the driver at the operational level and was tested in UK, German, and Greece DFOTs.

*Lane Departure Warning/Lane Keeping Assistance (LDW/LKA)*

A lane departure warning system provides feedback to the driver in case the vehicle is unintentionally leaving their own lane. This function evaluates the trajectory of the subject vehicle in relation to the lane boundaries like road markings or guard rails. In case an unintentional lane departure is detected (taking into account TLC (Time to Line Crossing) and turning indicators), a warning is issued to the driver. This warning might be visual, auditory or haptic. The function is intended to reduce crashes or incidents resulting from unintended lane departures. LDW was tested in Greek DFOTs and LKA was tested in German DFOT.

The following table is from deliverable 2.5.1 *Functions specification* and summarises the functions tested per LFOT and DFOT site for all impact assessment areas.
2.3. Participants in FOTs

In total, 1152 drivers (1092 LFOTs and 60 DFOTs) were included in the efficiency data analysis. Data from 8 LFOTs and 6 DFOTs were analysed. Overall, analyses include 6,634,064 km driven and approximately 143000 hours of driving.

Different data sources were used for different research questions even for data coming from LFOTs as not all data types were available for all participants. For example, logged data were used for investigating the effect to travel duration and questionnaire data for investigating perceived avoidance of traffic jams. These numbers correspond to the absolute overall participation.

No age differences were found between female and male participants. Male drivers were over-represented (three times more male drivers compared to female). Likewise, no differences were found in driving experience between female and male drivers (in years since they obtained their driving license). Most drivers had two decades of driving experience.
Table 6. Mean age (years) for female and male participants

<table>
<thead>
<tr>
<th>Gender</th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
<th>Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>885</td>
<td>41.6</td>
<td>11.67</td>
<td>22.2 ± 11.73</td>
</tr>
<tr>
<td>Female</td>
<td>267</td>
<td>40.3</td>
<td>10.68</td>
<td>19.4 ± 10.66</td>
</tr>
</tbody>
</table>

Driving frequency is similar for female and male participants, as it is evident from Figure 3. Most male (37.6%) and female (56.4%) participants drive between 10,000 and 20,000 km per year.

Drivers in both LFOTs and DFOTs completed a driving background questionnaire prior their participation. Participants rated their perceived driving experience, style and km driven on five-point rating scales (Likert scales). Participants stated that they were experienced drivers (3.96 ± 0.7*) with a balanced driving style (3.03 ± 0.6) and their annual mileage was more than 10,000 km but less than 20,000 km (2.4 ± 0.9).

Figure 2 presents median values for perceived driving experience, driving style and approximation of driving km per year for the whole sample.

**Figure 2. Median scores for reported driving experience, style and km driven per year**

*Mean ± standard deviation
2.4. Test designs

Different designs were used in various pilot sites. Differences also lie in the fact that both LFOTs and DFOTs were included.

However, research questions were either addressed by LFOTs or DFOTs depending on the nature and level of required analysis. The common perspective across sites was the within Subjects’ design. Conditions in FOTs altogether were “baseline” and “treatment”. Baseline conditions involved the absence of functions or a function compared to the treatment conditions where functions of bundles were tested. Hence, in most occasions a Within Subjects Design was implemented as it requires fewer participants in order to reveal significant results with fewer confounders. In case where Between Subjects Design was used (as it is less time consuming), participants were chosen with care. In some cases, it could be stated that they resembled pair-matched designs without the carry over effects.

Detailed descriptions of LFOT test designs can be found in Deliverable 3.5.1 (Pagle et al., 2012) and of DFOT test designs in Deliverable 3.6.1. (Koskimen et al., 2012).

![Figure 3. Driven km per year for female and male participants](image-url)
2.5. Data

Both subjective (i.e. questionnaires) and objective (i.e. logged) data were considered for the efficiency impact assessment. Travel diaries included partly qualitative data (open comments) but mostly quantitative (lengths, time stamps etc.) data were reported. Traffic simulation with different penetration rates was initially scheduled to be carried out but no differences were found for the data used for the simulation, therefore they were not performed.

2.5.1. Travel diaries

The TeleFOT travel diary was developed to address certain research questions and hypotheses. The travel diary was completed in paper format on a daily basis. Diaries were collected once in the before phase of the FOT (tested functions not yet available) and two or three times in the after phase (tested functions available to participants) depending on the length of the FOT. The length of each collection period was 1 week.

2.5.2. Logged data

All test vehicles were equipped with GPS loggers that collected at least the coordinates, heading and speed (frequency 1 Hz). Most of them also collected altitude and number of satellites visible based on the logger used. Some FOTs collected nomadic device and navigator usage logs such as function activation and traffic information messages received. However, this information was not collected for all FOTs (Koskinen, 2012).

In DFOTs highly instrumented vehicles were used. High frequency CAN bus logger data were recorded (e.g. signals of speed, acceleration, yaw rate, steering wheel angle). With radar sensors different performance indicators could be calculated (e.g. time/distance headway) and different warnings were activated (e.g. Forward Collision Warning (FCW), Lane Keep Assist (LKA)).

2.5.3. Questionnaires

Questionnaire data was collected from a background questionnaire and user uptake questionnaires. User uptake questionnaires were prepared per function. The participants completed separate questionnaires for each function they tested at the start of the trial (pre-questionnaire), once or twice during the treatment phase depending on its length (during-questionnaires), and once at the end of the trial (post-questionnaire).
2.6. Statistical analysis

The deliverables mentioned in Table 1 describe in detail not only the methodology followed within TeleFOT but also the procedures for developing the data specifications and the materials used for gathering qualitative data (questionnaires and travel diaries). Specifically, Deliverables 2.2.1 and 3.2.2b (also in Table 1) include an extensive description of the processes followed in order to select data gathered in FOTs across Europe. User Uptake questionnaires and the travel diaries can be found in the respective annexes (in 3.2.2b translated User Uptake questionnaires are included).

Two Excel files were created as reference documents for the indicators-especially for logged data- recorded in each site (e.g. time/duration, braking activation, speed summary statistics, etc.) for both LFOTs and DFOTs. These files acted as objective data “catalogues” and were available in the central database. In addition, metafiles for FOTs executed per site were available in the database. Metafiles included useful information for understanding the specifics for different FOTs. These two types of documents are important for data sharing among many different analysts.

Specific details about the data sources, data filtering, and statistical testing are included in the results section for each respective research question, as the diversity of data types and statistics performed do not allow for a unified data analysis plan and are discussed in detail in deliverables D3.5.1 and D43.6.1. Overall, t-tests were carried out for comparisons between two groups (continuous data) when normality was not violated and the sample size was adequate. If normality was violated (e.g. Levene test significant; p<.05) and/or sample size was small, then either log transformation was considered or a non parametric alternative (Wilcoxon test). If more than two groups were compared ANOVAs or Friedman ANOVA ranks test were used. The latter was applied if parametric assumptions were violated. In case of significant overall statistical test, further pairwise comparisons were carried out with adjusting the α value (Bonferroni correction). The α value was set at .05 in most cases.

Cross-tabulations were performed (χ² value reported) for investigating the effect of background or other situational variables. Consideration was made for distribution across cells to be above 5%. If sample size was small or distribution was not normal, then data were condensed in fewer categories in order to normalise distribution across cells (as increasing the sample size was no longer
an option). If none of these alterations were successful, then differences were reported but not statistically considered.

The effect of background data was investigated in LFOTs and in DFOTs situational variables were taken into consideration (e.g. road types and speed categories). In DFOTs, the sample sizes were small –compared to the number of participants in LFOTs–for investigating the effect of background variables.
3. IMPACTS

This chapter contains the results for traffic efficiency. Different types of data and results are used to answer different research questions. Significance was not attained for all research questions.

Impact assessment was based on research questions. These research questions were first selected, prioritised and then tested within WP4.5. Each sub-section presents the findings from a different research question and the respective hypotheses.

The following research questions were addressed (sub-section in brackets):

<table>
<thead>
<tr>
<th>EFFRQ</th>
<th>Question</th>
<th>Sub-section</th>
</tr>
</thead>
<tbody>
<tr>
<td>EFFRQ1</td>
<td>Is the travel time from origin to destination affected? (3.1)</td>
<td></td>
</tr>
<tr>
<td>EFFRQ2</td>
<td>Are there any delays avoided (3.2)</td>
<td></td>
</tr>
<tr>
<td>EFFRQ3</td>
<td>Are the vehicles’ speeds in the network increased/decreased? (3.3)</td>
<td></td>
</tr>
<tr>
<td>EFFRQ4</td>
<td>Is the time headway between the vehicles increased/decreased? (3.4)</td>
<td></td>
</tr>
<tr>
<td>EFFRQ5</td>
<td>Are there any traffic jams avoided? (3.5)</td>
<td></td>
</tr>
<tr>
<td>EFFRQ6</td>
<td>Is the distance from the preceding vehicle smaller/larger? (3.6)</td>
<td></td>
</tr>
</tbody>
</table>

Some tables depicting results from further analysis were annexed. Whenever needed they are referred in the document.

3.1. Journey Duration

The duration of journeys was taken into consideration for answering EFFRQ1 and, specifically, the following hypothesis was tested.

**EFF H1.1 Travel times are likely to increase/decrease (when device is used compared to when device is not used)**

3.1.1. Method

*Data consideration*

Representation from northern, central and southern communities was achieved and analysis is based on logged data (i.e. objective data) and travel diaries. All test sites (i.e. LFOTs) were included in the analysis. The analysis was based on frequently made journeys. In practice, same origin destination (OD) pairs were searched in baseline and treatment conditions for each participant. The radius of 100 metres was used to determine the locations where the vehicles had stopped.
It is evident from the table below (Table 7) that different combinations of functions were tested in different sites.

**Anticipated effects of functions and their combinations**

It was anticipated that navigation support and traffic information are likely to affect travel time, as different routes may be suggested by occasion. The effect of speed alert or speed information is considered secondary. As functions are found in bundles, the assumption for separate functions’ effect to traffic efficiency is difficult to estimate except for separate pilot sites where baseline and treatment conditions differed on one function. As impact assessment focused on existing nomadic devices, then these functions were tested in bundles.

**Table 7. LFOT logged data specifics for journey duration**

<table>
<thead>
<tr>
<th>FOT</th>
<th>Function(s)</th>
<th>Data Type</th>
<th>Number of participants</th>
<th>Total driving km</th>
<th>Total driving hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finland, LFOT</td>
<td>GD, SI/SA, TI</td>
<td>Logged</td>
<td>125</td>
<td>334,013</td>
<td>7,489</td>
</tr>
<tr>
<td>Italy, LFOT</td>
<td>NA, SI/SA</td>
<td>Logged</td>
<td>150</td>
<td>3,325,630</td>
<td>72,312</td>
</tr>
<tr>
<td>Spain, Valladolid LFOT</td>
<td>NA, SI/SA</td>
<td>Logged</td>
<td>120</td>
<td>871,508</td>
<td>19,516</td>
</tr>
<tr>
<td>Spain, Madrid LFOT</td>
<td>GD, TI</td>
<td>Logged</td>
<td>132</td>
<td>1,446,316</td>
<td>58,025</td>
</tr>
<tr>
<td>Sweden LFOT2</td>
<td>GD, NA, TI</td>
<td>Logged</td>
<td>87</td>
<td>622,244</td>
<td>12,865</td>
</tr>
<tr>
<td>Sweden, LFOT4</td>
<td>TI</td>
<td>Logged</td>
<td>260</td>
<td>465,075</td>
<td>7,944</td>
</tr>
<tr>
<td>UK, LFOT</td>
<td>NA, SI/SA</td>
<td>Logged</td>
<td>60</td>
<td>192,740</td>
<td>3,785</td>
</tr>
<tr>
<td>Greece, LFOTs (1-3)</td>
<td>NA, SI, SA, TI</td>
<td>Logged</td>
<td>148</td>
<td>805,456</td>
<td>18,842</td>
</tr>
</tbody>
</table>

All origin destination pairs (OD pairs) that a single test participant drove at least once during the baseline phase and at least once during the treatment phase were included in the analysis. One origin destination pair was regarded as one
sample per participant. Participants contributed varying number of these pairs. Outliers that were substantially outside the data distribution were removed, in most cases a limit of four times standard deviation was used.

Mean duration was calculated for both periods for each origin destination pair, and compared. Analysis covers only the possibility to use the function. Logging did not include the actual use of system, thus, the impacts of actual use could not be analysed based on logger data.

**Statistical Testing**

Paired-sample t-test was used to test for differences between baseline and treatment conditions.

Hypotheses:

\[ H_0: \text{The function has no influence on the duration} \]
\[ H_1: \text{The function has an influence on the duration} \]

### 3.1.2. Results

Statistical significance of duration of journeys between different OD pairs was calculated by function bundle. For those participants in Finnish LFOTs who had only traffic information service in use throughout testing phase no statistically significant impacts on duration of journeys between comparable origins and destinations were found.

The statistically significant differences were the following:

- Duration was **13.1% longer** with **green driving** than without it in Finnish LFOT for those participants who had **traffic information** and **speed information/alert** as baseline functions;
- **18% longer** with **green driving** compared to **speed information/alert**;
- **8.8% shorter** with **navigation and speed information/alert** in Valladolid LFOT;
- Duration was **10% shorter** with **green driving, traffic information and navigation** in Swedish LFOT2, when compared to **baseline without any functions**;
- **9.7% shorter** with **navigation and traffic information** when compared to **only navigation** in Greek LFOT3.
In bold (Table 8) are shown the functions or bundles of functions added to the treatment condition and are actually different from baseline condition. In case of differences, the addition of certain functions or bundles of functions is assumed to be related with the observed changes in duration of paired journeys.
Table 8. Mean duration between comparable origins and destinations in baseline and treatment phase ($t$, $p$ values included)

<table>
<thead>
<tr>
<th>FOT</th>
<th>Functions</th>
<th>N</th>
<th>Duration (min)</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Baseline (Mean)</td>
<td>Treatment (Mean)</td>
<td>Baseline (Standard Deviation)</td>
<td>Treatment (Standard Deviation)</td>
<td>$t$</td>
</tr>
<tr>
<td>Finland LFOT</td>
<td>TI</td>
<td>12</td>
<td>20.6</td>
<td>23.9</td>
<td>10.6</td>
<td>9.2</td>
<td>-1.440</td>
</tr>
<tr>
<td>Finland LFOT</td>
<td>TI, GD, SI/SA</td>
<td>8</td>
<td>49.6</td>
<td>38.1</td>
<td>11.8</td>
<td>9.1</td>
<td>1.530</td>
</tr>
<tr>
<td>Finland LFOT</td>
<td>TI, SI/SA</td>
<td>48</td>
<td>31.5</td>
<td>31.4</td>
<td>18.7</td>
<td>14.6</td>
<td>0.035</td>
</tr>
<tr>
<td>Finland LFOT</td>
<td>TI, SI/SA</td>
<td>191</td>
<td>33.9</td>
<td>40.0</td>
<td>28.3</td>
<td>40.2</td>
<td>-2.251</td>
</tr>
<tr>
<td>Finland LFOT</td>
<td>TI, SI/SA, GD</td>
<td>75</td>
<td>27.4</td>
<td>31.0</td>
<td>17.0</td>
<td>21.5</td>
<td>-1.672</td>
</tr>
<tr>
<td>Finland LFOT</td>
<td>TI, GD</td>
<td>85</td>
<td>29.8</td>
<td>29.9</td>
<td>21.8</td>
<td>21.6</td>
<td>-0.023</td>
</tr>
<tr>
<td>Spain, Valladolid LFOT</td>
<td>NA, SI/SA</td>
<td>1174</td>
<td>17.1</td>
<td>16.3</td>
<td>15.2</td>
<td>10.2</td>
<td>2.277</td>
</tr>
<tr>
<td>Spain, Madrid LFOT</td>
<td>GD</td>
<td>7818</td>
<td>9.05</td>
<td>9.09</td>
<td>7.23</td>
<td>7.63</td>
<td>-0.641</td>
</tr>
<tr>
<td>FOT</td>
<td>Functions</td>
<td>N</td>
<td>Duration (min)</td>
<td>t</td>
<td>p</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------------------</td>
<td>-----------</td>
<td>-----</td>
<td>----------------</td>
<td>------</td>
<td>--------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spain, Madrid LFOT</td>
<td>TI</td>
<td>6447</td>
<td>8.57, 8.58, 6.45, 6.48</td>
<td>-0.208</td>
<td>0.836</td>
<td></td>
<td></td>
</tr>
<tr>
<td>UK LFOT</td>
<td>NA, SI/SA</td>
<td>291</td>
<td>18.8, 18.0, 19.2, 18.9</td>
<td>0.977</td>
<td>0.329</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Italy LFOT</td>
<td>NA, SI/SA</td>
<td>3897</td>
<td>11.9, 11.9, 12.3, 12.1</td>
<td>0.646</td>
<td>0.518</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sweden LFOT4</td>
<td>TI</td>
<td>263</td>
<td>25.6, 26.5, 18.6, 19.1</td>
<td>-1.598</td>
<td>0.111</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sweden LFOT2</td>
<td>GD, NA, TI</td>
<td>1163</td>
<td>17.5, 15.8, 23.0, 19.7</td>
<td>2.905</td>
<td>0.004**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Greece LFOT1</td>
<td>NA</td>
<td>414</td>
<td>34.1, 32.7, 53.3, 45.3</td>
<td>0.641</td>
<td>0.522</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Greece LFOT2</td>
<td>NA, SI</td>
<td>456</td>
<td>32.3, 34.6, 39.3, 50.7</td>
<td>-1.111</td>
<td>0.267</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Greece LFOT3</td>
<td>NA, TI</td>
<td>430</td>
<td>41.4, 37.4, 64.8, 58.6</td>
<td>2.176</td>
<td>0.030**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Greece LFOT4</td>
<td>NA, SA</td>
<td>543</td>
<td>37.4, 39.9, 61.0, 69.2</td>
<td>-1.250</td>
<td>0.212</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*/**Statistically significant difference
Plots were made for those data that indicated statistically significant impact on duration. Although the mean duration was longer with the green driving application than without it, Figure 4 shows that for most long journeys (over 45 min duration), the duration is shorter in the treatment phase than in the baseline phase. Mean duration in treatment condition could have been affected by some much longer journeys.

Figure 4. Impact of green driving application on duration of frequently made journeys in Finnish LFOT

Use of traffic information and speed information/alert was considered here as baseline condition. The treatment condition differed from baseline because of the addition of green driving support in the Finnish LFOT.
Figure 5. Impact of speed information/alert on duration of frequently made journeys in Finnish LFOT.

Again, for Figure 5, it should be noted that use of green driving application was considered as baseline condition. In the same figure, it is evident that dispersion is greater for traffic information and green driving condition than traffic and speed information and alert condition. Handling of dispersion is discussed in the next sub-section.

Figure 6. Impact of navigation and speed information/alert on duration of frequently made journeys in Valladolid LFOT

Duration was significantly decreased because of bundle of functions (navigation support with speed limit information/speed alert). It is evident also that variation...
in duration is decreased when the functions are used compared to free driving (no functions) (Figure 6). Similarly, the use of another bundle of functions (navigation support with traffic information and green driving) decreased significantly the journey duration and variation when compared to baseline condition in Swedish LFOT2 (Figure 7). Although, different combination of functions were used in two different pilot sites, the effect is similar when compared to no functions at all.

![Figure 7. Impact of green driving, traffic information and navigation on duration of frequently made journeys in Swedish LFOT2](image)

![Figure 8. Impact of navigation and traffic information application on duration of frequently made journeys in Greek LFOT3](image)
Navigation was considered here as baseline condition (Figure 8). Traffic information significantly decreased journey duration in Greek LFOT3 when compared to just navigation support.

**Spread of data**

If there is no impact, the duration should be longer in 50% of OD pairs in treatment and shorter in 50% of OD pairs in baseline and there should not be greater than 10% differences. In bold, the functions that exist in treatment condition and not in baseline. If all functions are in bold, then in treatment condition no function was tested. According to spread of data assumption, in order to accept there is no impact, then all three assumptions should hold true for each row in the following table (Table 9). Evidently, this is not true and impact for efficiency was revealed for journey duration.

**Table 9. Proportion of OD pairs with difference in duration**

<table>
<thead>
<tr>
<th>FOT</th>
<th>Functions</th>
<th>N</th>
<th>Duration longer in baseline conditions</th>
<th>Duration at least 10% longer in baseline conditions</th>
<th>Duration at least 10% longer in treatment conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finland</td>
<td>TI</td>
<td>12</td>
<td>33.3</td>
<td>25.0</td>
<td>50.0</td>
</tr>
<tr>
<td>LFOT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Finland</td>
<td>TI</td>
<td>8</td>
<td>62.5</td>
<td>50.0</td>
<td>25.0</td>
</tr>
<tr>
<td>LFOT</td>
<td>TI, GD, SI/SA</td>
<td>48</td>
<td>48.0</td>
<td>44.0</td>
<td>40.0</td>
</tr>
<tr>
<td>Finland</td>
<td>TI, SI/SA</td>
<td>191</td>
<td>42.0</td>
<td>30.6</td>
<td>43.5</td>
</tr>
<tr>
<td>LFOT</td>
<td>TI, GD</td>
<td>75</td>
<td>48.0</td>
<td>41.3</td>
<td>49.3</td>
</tr>
<tr>
<td>Finland</td>
<td>TI, SI/SA</td>
<td>38.8</td>
<td>34.8</td>
<td>35.3</td>
<td></td>
</tr>
<tr>
<td>LFOT</td>
<td>TI, GD</td>
<td>117</td>
<td>46.0</td>
<td>27.9</td>
<td>26.1</td>
</tr>
<tr>
<td>Spain</td>
<td>NA, SI/SA</td>
<td>30.6</td>
<td>23.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Valladolid LFOT</td>
<td>GD</td>
<td>781</td>
<td>23.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Copyright TeleFOT Contract N 224067
Hence, it is concluded that the hypothesis is accepted that change in travel duration is decreased with the use of nomadic devices. In particular green driving support and traffic information appear to be more related (primary) when compared to speed information and speed alert (secondary), as initially was anticipated. Thus, the null hypothesis is rejected. Journey duration is an indicator affected by other variables and further correlational analysis was performed.

<table>
<thead>
<tr>
<th>FOT</th>
<th>Functions</th>
<th>N</th>
<th>Duration longer in baseline (%)</th>
<th>Duration at least 10%</th>
<th>Duration at least 20%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Madrid LFOT</td>
<td></td>
<td>8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spain Madrid LFOT</td>
<td>-</td>
<td>TI</td>
<td>644 7</td>
<td>28.8</td>
<td>20.9</td>
</tr>
<tr>
<td>UK LFOT</td>
<td></td>
<td>291</td>
<td>52.2</td>
<td></td>
<td>44.7</td>
</tr>
<tr>
<td>Italy LFOT</td>
<td></td>
<td>389</td>
<td>41.6</td>
<td></td>
<td>26.4</td>
</tr>
<tr>
<td>Sweden LFOT4</td>
<td>-</td>
<td>TI</td>
<td>263</td>
<td>46.3</td>
<td>29.5</td>
</tr>
<tr>
<td>Sweden LFOT2</td>
<td>-</td>
<td>GD, NA, TI</td>
<td>116 8</td>
<td>57.4</td>
<td>45.5</td>
</tr>
<tr>
<td>Greece LFOT1</td>
<td>-</td>
<td>NA</td>
<td>414</td>
<td>46.1</td>
<td>35.3</td>
</tr>
<tr>
<td>Greece LFOT2</td>
<td>NA</td>
<td>NA, SI</td>
<td>456</td>
<td>52.4</td>
<td>42.3</td>
</tr>
<tr>
<td>Greece LFOT3</td>
<td>NA</td>
<td>NA, TI</td>
<td>430</td>
<td>56.1</td>
<td>44.3</td>
</tr>
<tr>
<td>Greece LFOT4</td>
<td>NA</td>
<td>NA, SA</td>
<td>546</td>
<td>52.9</td>
<td>39.6</td>
</tr>
</tbody>
</table>
Correlation to Questionnaire data

Correlation between logger and questionnaire data was determined by comparing the assessed change direction (decrease or increase) in the questionnaire to the change direction in logger data.

In Green driving and Navigation, the questionnaire data was in concordance with logger data in all LFOTs, except in Italian LFOT, where there was no change based on the logger data and decrease in questionnaire data (32%). In Speed information/alert, the questionnaire data was compatible with logger data only for Finnish and UK LFOTs, and in Traffic information for Greek LFOT3 and Swedish LFOT2.

The only statistically significant differences between baseline and treatment means in logger data were for Swedish LFOT2 and Spanish Valladolid LFOT for all functions, for Finnish LFOT with Green driving and for Greek LFOT with Traffic information. Only the Spanish Valladolid LFOT with Speed information/alert was not in concordance with questionnaire data. However, the bundle impact was present in the logger data, whereas questionnaire data was collected function specific.

The LFOTs where the logger data had statistically significant differences between treatment and baseline means were examined on the participant group level. The questionnaire data was concordant with logger data for Swedish LFOT2 Green driving, Traffic information, Navigation, and Spanish Valladolid LFOT with Navigation where the participants had assessed there to be a decrease of duration in questionnaire data also had more negative values in logger data. For other LFOTs, the mean difference (treatment-baseline) was also negative, except for Swedish LFOT2 where the less frequent positive values were larger than the negative ones. The only LFOTs where participants assessed a change in a different direction than the logger data showed, were the Finnish LFOT for Green driving and Spanish Valladolid LFOT for Speed information/alert. For both these LFOTs the logger data showed decrease in duration, whereas the questionnaire data replies showed an increase.
Table 10. Direction change for journey duration in questionnaire and logger data

<table>
<thead>
<tr>
<th>LFOT/function (Q)</th>
<th>Function bundle (log)</th>
<th>Change (Q)</th>
<th>Mean change (treatment-baseline) log</th>
<th>Standard deviation</th>
<th>Positive values (%)</th>
<th>Negative values (%)</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finland, Green driving</td>
<td>TI&amp;SI/SA -&gt; TI&amp;GD</td>
<td>increase</td>
<td>0.72</td>
<td>1.58</td>
<td>33</td>
<td>67</td>
<td>3</td>
</tr>
<tr>
<td>Sweden LFOT2, Green driving</td>
<td>GD, TI, NA</td>
<td>decrease</td>
<td>-7.49</td>
<td>17.22</td>
<td>40</td>
<td>60</td>
<td>5</td>
</tr>
<tr>
<td>Sweden LFOT2, Traffic information</td>
<td>GD, TI, NA</td>
<td>decrease</td>
<td>-6.42</td>
<td>14.11</td>
<td>14</td>
<td>86</td>
<td>7</td>
</tr>
<tr>
<td>Sweden LFOT2, Navigation</td>
<td>GD, TI, NA</td>
<td>decrease</td>
<td>2.36</td>
<td>9.67</td>
<td>37</td>
<td>63</td>
<td>8</td>
</tr>
<tr>
<td>Spain Valladolid LFOT, Speed information/alert</td>
<td>SI/SA, NA</td>
<td>increase</td>
<td>2.53</td>
<td>7.70</td>
<td>33</td>
<td>58</td>
<td>12</td>
</tr>
<tr>
<td>Spain Valladolid LFOT, Navigation</td>
<td>SI/SA, NA</td>
<td>decrease</td>
<td>-5.65</td>
<td>19.90</td>
<td>26</td>
<td>65</td>
<td>34</td>
</tr>
</tbody>
</table>

Correlations to background variables

Duration changes were analysed by age and familiarity of functions. The analyses were made function/bundle specific, and the groups that had a certain change (decrease/increase) in journey duration were compared to those who had a change in a different direction or no change at all. The LFOTs and functions were included where there were statistically significant differences between treatment and baseline conditions. The value was considered to have changed if the difference between baseline and treatment mean was more than 10% of the baseline value. Chi-square test was used to determine if there was a connection between previous experience of the function and the function use during the trial.
(Cell frequencies were not in all cases sufficient related to test assumptions, but the test was carried out regardless.)

There was strong dependence between the previous function use variables which might have contributed to the analyses. Age (calculated from date of birth) was classified into four groups (1934-1949, 1950-1965, 1966-1981 and 1982-1997). Because of uneven distributions, age could be studied for Finnish LFOT, Swedish LFOT2, Italian LFOT and UK LFOT, and gender for Swedish LFOT2 and UK LFOT.

Familiarity of function use was determined through four categories: no experience on function, some previous information on function but no use experience, some use experience and considerable use experience. Most drivers described themselves as balanced drivers (42-84%), so differences between groups were not studied in regard to driving style.

There were statistically significant differences between the group that had an increase in duration and the group that had a decrease or no change in Finnish LFOT with Traffic information and Green driving in age distribution ($\chi^2(36) = 7.101, p = .069$) and previous green driving experience in Finnish LFOT with Green driving and Speed information/alert ($\chi^2(36) = 4.617, p = .099$). The results were statistically significant also for Swedish LFOT2 in previous traffic information experience ($\chi^2(31) = 7.811, p = .05$). In Finnish LFOT those who had used green driving before and belonged to the second age group (1950-1965), had a change in journey duration more often than those who did not have previous experience on the function and belonged to other age groups. In Swedish LFOT2 there was an overall difference in the previous use distributions for the two groups. In Swedish LFOT2 with navigation, none of the participants who had some previous information on the function (but had not used it) had an increase in journey duration. However, for this LFOT and this function the test results were not statistically significant. Questionnaires did not reveal any significant difference.

**Rush hour journeys**

Rush hour was determined to be from 7-9 a.m. and 3-6 p.m. The difference between baseline and treatment means was larger in rush hour OD pairs than all OD pairs for Finnish (SI/SA, GD&SI/SA) UK, Italian, Madrid LFOT (TI & GD), Greek LFOT1 and Greek LFOT2. For other LFOTs it was smaller (Finnish GD, Spain, Sweden4, Sweden2, Greek3 and Greek4). The difference was in a different direction than with all OD pairs for Finnish LFOT (SI/SA), Madrid LFOT (TI), Greek LFOT1 (NA), Greek LFOT2 (SI) and Greek LFOT3 (TI).
There were statistically significant differences between the means for Finnish LFOT with Green driving \((t=2.251, p=.026)\), Finnish LFOT with Green driving and Speed information/alert \((t=-1.672, p=.099)\), Spanish Valladolid LFOT \((t=2.277, p=.023)\), Swedish LFOT2 \((t=2.905, p=.004)\) and Greek LFOT3 (TI) \((t=2.176, p=.03)\) for all OD pairs. However, in rush hour OD pairs these differences were statistically significant only for Finnish LFOT (GD&SI/SA) \((t=-2.767, p=.007)\) and Swedish LFOT2 \((t=2.598, p=.01)\).

For UK LFOT, Italian LFOT and Greek LFOT1 there was no statistically significant difference for all OD pairs, but they were found for rush hour OD pairs.

Rush hour traffic means could not be calculated for two Finnish LFOT groups (TI-TI and TI-TI&GD&SI/SA) because the number of OD pairs was too low.

**Daytime journeys**

Daytime was determined to be from 9 a.m. to 3 p.m. The difference between baseline and treatment means was smaller in daytime journey OD pairs for most LFOTs. Only for the Finnish (SI/SA), Madrid LFOT (TI), and Greek LFOT1 (navigation) was the difference larger in daytime journey OD pairs when compared to all OD pairs. The difference was in the opposite direction than with all OD pairs only for Finnish LFOT (groups with SI/SA, GD), Madrid LFOT (GD), and Greek LFOT3 (TI).

There were statistically significant differences between the means for Finnish LFOT with Green driving \((t=-2.251, p=.026)\), Finnish LFOT with Green driving and Speed information/alert \((t=-1.672, p=.099)\), Spanish Valladolid LFOT \((t=-2.277, p=.023)\), Swedish LFOT2 \((t=2.905, p=.004)\) and Greek LFOT3 ((\(t=2.176, p=.03;\) Traffic information) for all OD pairs. However, in daytime journey OD pairs these differences were statistically significant only for the Finnish LFOT (GD & SI/SA) \((t=-2.130, p=.039)\) and Swedish LFOT2 \((t=1.889, p=.059)\).

Daytime journey means could not be calculated for three Finnish LFOT groups (TI \(\rightarrow\) TI, TI \(\rightarrow\) TI&GD&SI/SA and TI, SI/SA \(\rightarrow\) TI) because the number of OD pairs was too low.

**Night time journeys**

Night time was determined to be from 6 p.m. to 7 a.m. The difference between baseline and treatment means was larger in night time journey OD pairs for Finnish LFOT with Speed information/alert, UK, Italian, Madrid LFOT (TI & GD),
Greek LFOT1 and Greek LFOT2. For other LFOTs it was smaller (Finnish GD, Finnish GD&SI/SA, Spain, Sweden4, Sweden2, Greek3 and Greek4). The difference was in the opposite direction than with all OD pairs for Finnish SI/SA, Madrid LFOT (TI), UK and Italian LFOTs.

There were statistically significant differences between the means for Spanish Valladolid LFOT ($t=2.277$, $p=.023$), Finnish LFOT with Green driving($t=-2.251$, $p=.026$), Finnish LFOT with Green driving and Speed information/alert ($t=-1.672$, $p=.099$), Swedish LFOT2 ($t=2.905$, $p=.004$) and Greek LFOT3 (TI) ($t=2.176$, $p=.03$) for all OD pairs. However, in night time journey OD pairs these differences were not statistically significant anymore.

For Madrid LFOT (TI), Greek LFOT1 and Greek LFOT2 there was no statistically significant difference for all OD pairs, but they were found for rush hour OD pairs.

Night time journey means could not be calculated for two Finnish LFOT groups (TI $\rightarrow$ TI and TI $\rightarrow$TI&GD&SI/SA) because the number of OD pairs was too low.

**Travel diary data analysis**

Commuting by car was selected from travel diary (TD) data. Mean duration of those journeys when no function was in use in the first travel diary data collection week was compared with mean duration of later travel diary data collection weeks when certain function was in use. Means were calculated for each travel diary data collection week for all those participants with at least one journey of interest. It did not matter when the function was used nor if other functions were used, too. The bundle in which the function was given to the driver may have had an impact. If the mean duration of a participant was at least 100% greater in treatment than in baseline, then the sample was excluded. Data were compared with paired-sample t-test one travel diary data collection week at a time. Only those results were considered where at least 10 participants contributed to the sample were considered.

In Finnish LFOT with commuting journeys when green driving was in use both periods show a decrease in the duration, the second treatment period travel diary indicating statistically significant decrease. This result is contradictory to logged data result of green driving increasing duration. Nevertheless the durations of commuting journeys when no functions are in use decreased and although not statistically significant this impact is likely caused by seasonal variation in travel times (baseline collected in November/December for most with winter coming and...
the second treatment phase travel diary collected in May for most with winter already passed).

Greek LFOT results show very strong variation in commuting travel times. As the baseline mean duration is clearly shorter for those who have not used the functions when comparing for those who have, it more likely indicates that very bad traffic congestion during baseline phase motivated participants to use the functions. However, as big differences in duration are seen also in the no functions in use comparison, the impact is at least partly caused by seasonal variations. Nevertheless, based on these results, it is plausible that navigation and traffic information have contributed to decreases in the duration which is in line with logged data results.

Italian LFOT results indicate that those participants with longer commuting journeys than average participant used speed information/alert system in their commuting journeys. Although, it makes sense to use speed information/alert for longer journeys, no statistically significant impact of speed information/alert function was found.

In Spanish LFOT1, there were no statistically significant differences in durations. All treatment phase mean durations were shorter than the baseline. This finding either indicates seasonal trend or the impact of navigation which transfers also to journeys where no functions are in use. It is clear that you do not need to use navigation for all commuting journeys as these journeys are repeated so frequently, one memorises it and after that there is no need to use the navigator for navigation purpose any more.

In Swedish LFOT2, all mean durations were shorter for treatment period than for baseline period. The first treatment phase travel diary week results were statistically significant for navigation and speed information/alert (in Swedish LFOT2 a feature included in the navigator) but also for no functions in use. Therefore, this can indicate the impact of navigation function or equally seasonal variation.

In UK data only commuting journeys with no function in use had sufficiently large sample size and it was clear that functions used during commuting were very seldom.
Table 11. Average duration of commuting journey when a certain function was in use or no function was in use (treatment period travel diaries) and average duration of the commuting journeys of the same participants in baseline period (1st travel diary) with no function in use (baseline/treatment, min), sample size at least 10 observations, statistically significant differences bolded.

<table>
<thead>
<tr>
<th>Treatment period</th>
<th>Navigation</th>
<th>Traffic information</th>
<th>Speed information/alert</th>
<th>Green driving</th>
<th>No functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finland LFOT</td>
<td></td>
<td>-</td>
<td>-</td>
<td>21.5/20.9</td>
<td>22.5/22.7</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Greece LFOT</td>
<td></td>
<td>-</td>
<td>-</td>
<td>22.2/19.3</td>
<td>24.2/22.7</td>
</tr>
<tr>
<td>FOT01</td>
<td></td>
<td></td>
<td></td>
<td>34.2/35.3</td>
<td></td>
</tr>
<tr>
<td>FOT02</td>
<td></td>
<td></td>
<td></td>
<td>44.0/32.7</td>
<td></td>
</tr>
<tr>
<td>FOT03</td>
<td></td>
<td>57.8/30.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FOT04</td>
<td></td>
<td></td>
<td></td>
<td>29.7/23.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>60.8/32.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Italy LFOT</td>
<td></td>
<td></td>
<td></td>
<td>27.7/23.3</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spain LFOT1</td>
<td></td>
<td></td>
<td></td>
<td>27.0/22.8</td>
<td>23.6/20.7</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>25.3/24.1</td>
<td>23.6/20.7</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td>25.8/22.9</td>
<td>23.2/20.4</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td>22.7/22.0</td>
<td>23.9/20.7</td>
</tr>
<tr>
<td>Sweden LFOT2</td>
<td></td>
<td>37.8/27.9</td>
<td>38.0/32.4</td>
<td>36.5/29.0</td>
<td>28.9/22.3</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>37.2/35.9</td>
<td>33.6/31.2</td>
<td>45.7/37.5</td>
<td>59.1/25.5</td>
</tr>
</tbody>
</table>

3.1.3. Discussion and Conclusions
Mostly logged data were used to assess the hypothesis “Travel times are likely to increase/decrease (when device is used compared to when device is not used)”. The only statistically significant differences were that the duration was 13.1% longer with green driving than without it in Finnish LFOT for those participants who had traffic information and speed information/alert as baseline functions. 8.8% shorter with navigation and speed information/alert in Valladolid LFOT. 10% shorter with green driving, traffic information and navigation in Swedish LFOT2 when compared to baseline without any functions, and 9.7% shorter with navigation and traffic information when compared to only navigation in Greek LFOT3.

Consequently, it seems that both green driving and bundle navigation and speed information/alert may affect the duration. However, it must be noted that green
driving in bundle with navigation and traffic information in Sweden showed a contradictory decrease in duration while in Finnish LFOT those participants who had “traffic information and speed information/alert” in baseline and “traffic information and green driving” in treatment showed increase in duration (in line with above result). In line with the Valladolid result, the same bundle “navigation and speed information/alert” decreased duration in UK although the difference was not statistically significant. The Swedish result described above indicated that the decrease caused by navigation is stronger than the increase caused by navigation.

In Green driving and Navigation, the questionnaire data was in concordance with logger data in all LFOTs, except in Italian LFOT. In Speed information/alert, the questionnaire data was compatible with logger data only for Finnish and UK LFOTs, and in Traffic information for Greek LFOT3 and Swedish LFOT2. On participant group level (if those who had a decrease/increase in questionnaire also had the change in logger data) the logger data was in concordance with the questionnaire data for Swedish LFOT2 with Green driving, Traffic information, and Navigation, and Spanish Valladolid LFOT with Navigation.

There were statistically significant differences between the group that had an increase in duration and the group that had a decrease or no change in Finnish LFOT in age distribution and previous green driving experience, and for Swedish LFOT2 in previous traffic information experience.

For rush hour, daytime and night time journeys the difference between origin destination pairs was smaller than for all journeys in most LFOTs. There were three LFOTs (Finnish GD, Spanish Valladolid and Greek LFOT3 (TI)) where there was a statistically significant difference in all journeys but not in rush hour or daytime journeys. For UK, Italian and Greek LFOT1 there were statistically significant differences in daytime journeys but not in all journeys. For night time journeys, there were five LFOTs (Spanish, Finnish LFOT GD, Finnish GD&SI/SA, Swedish LFOT2 and Greek LFOT3 with Traffic information) that had a statistically significant difference between baseline and treatment in night time journeys, but the difference could not be seen in all journeys. On the contrary, in Madrid LFOT (TI), Greek LFOT1 (NA) and Greek LFOT2 (SI) there was a difference only for all journeys.
3.2. Perceived change in delays

The presence of delays is a common road traffic phenomenon for traffic efficiency. If fewer delays are reported then this could have a positive effect on traffic efficiency. Delays are the outcome of many traffic related phenomena (e.g. congestion, accidents, re-routing because of road works). The following two-tailed hypothesis was tested.

**EFF-H2.1 Travel times are likely to increase/decrease (when device is used compared to when device is not used)**

Objective investigation of delays would rely heavily on logged data about travel and journey duration. As these data were analysed for investigating other research questions, another approach was adopted. As the focus is the impact assessment of existing nomadic devices, then qualitative data are of increased importance. In other words, if users believe the use of a device decreases delays, then they would probably use it and, consequently, penetration to traffic would increase because users believe it affects delays. Secondly, perceived delays do have inherent pitfalls as most subjective assessments. Subjective estimates give an impression and a feeling of what happened. Sometimes people forget about exact events and hold mostly beliefs about an event rather a description of the actual event. These are the attributional characteristics users place on facts and situations. Thirdly, the analysis of the same data for similar hypotheses was decided to be avoided (i.e. avoided using journey duration for answering EFF-RQ2 as these data are already used for EFF-RQ1).

As subjective data (i.e. questionnaires) were used for testing and answering this research question, data from all LFOTs were used. LFOT data are longitudinal data and could reveal potential changes in attitudes and beliefs, something not possible with DFOT data.

Comparisons were not possible to be performed because of no respective questions in the pre-questionnaire. The values of including such a question in the pre-questionnaire would be low as it would probably investigate pre-acceptance of the function rather than actual avoidance of delays.

### 3.2.1. Methods

*Data considerations*

The analysis is based on the question item 7.16 from the post User-Uptake questionnaires used by all test sites. Participants were asked to rate any changes
in encountered delays on a five point Likert scale. Representation was achieved by all communities and 696 post-questionnaires were completed. Overall response rate was reduced by 37% when they were using the navigation support or the traffic information functions. The lowest response rate was recorded in Finnish LFOT (58%) and the highest response rate in Greek LFOT 1 (93%). The Greek LFOT 2 (87%) was the only test site that revealed statistical significant decrease in reported encountered delays when using the traffic information function.

Table 12. Data sources and functions tested for perceived change in delays

<table>
<thead>
<tr>
<th>FOT</th>
<th>Function(s)</th>
<th>Data Type</th>
<th>Number of participants (*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greece, LFOT3</td>
<td>Traffic Information</td>
<td>Questionnaire</td>
<td>Before: 83, Post:72</td>
</tr>
<tr>
<td>Italy, LFOT</td>
<td>Navigation Support</td>
<td>Questionnaire</td>
<td>Before:139, Post:113</td>
</tr>
<tr>
<td>Spain, LFOT</td>
<td>Navigation Support</td>
<td>Questionnaire</td>
<td>Before:117, Post:95</td>
</tr>
<tr>
<td>Sweden, LFOT1</td>
<td>Navigation Support</td>
<td>Questionnaire</td>
<td>Before:94, Post:68</td>
</tr>
<tr>
<td>Sweden, LFOT4</td>
<td>Traffic Information</td>
<td>Questionnaire</td>
<td>Before: 234, Post:35</td>
</tr>
<tr>
<td>Sweden, LFOT2</td>
<td>Traffic Information</td>
<td>Questionnaire</td>
<td>Before: 94, Post:61</td>
</tr>
<tr>
<td>UK, LFOT</td>
<td>Navigation Support</td>
<td>Questionnaire</td>
<td>Before:77,Post:46</td>
</tr>
<tr>
<td>Finland, LFOT</td>
<td>Traffic Information</td>
<td>Questionnaire</td>
<td>Before: 118, Post:68</td>
</tr>
</tbody>
</table>

(*) Number of available questionnaires (Before= at the beginning of the test, Post = at the end of the test)
Further to basic questionnaire analysis, potential influences of the following background factors were also investigated:

- Km driven on average per year
- Driving experience
- Type of roads driven

Anticipated effects of functions and their combinations

The impact of traffic information was anticipated to have the greater impact to participants’ opinion and other functions (e.g. green driving support, speed limit information, speed alert) were not anticipated to affect avoidance of delays and, therefore, they were not considered for this analysis.

Statistical Testing

Chi-Square Test for Equal Proportions and Binomial test for significance assessment were carried out. Further, Fisher and Chi-Square tests were used for investigating the influence of annual mileage and driving experience on perceived change (or no change) in delays. Finally, ANOVA test was used for evaluating the influence of type of roads driven.

3.2.2. Results

Navigation Support function

For all countries the majority of participants reported that they thought that the navigation support function made no changes to perceived delays: 55.5% of participants for Greece to 93% of UK.

The distribution of answers from five LFOTs (five possible options; radical decrease–radical increase) about perceived change in encountered delays using the Navigation support function is shown in Figure 9.
Figure 9. Perceived change in encountered delays because of using the navigation support function

A small percentage of participants (from 0% to 9%) had a negative perception and declared a slight increase in their delays. The percentage of users reporting increase in delays, because they were using the navigation support system, is slightly greater than the users who reported decrease. This would probably hold true because users sometimes follow the routes the navigation system offers them—as they are the “fastest” or “shortest” options—and these routes are usually different from the ones they usually follow. Sometimes, drivers may end up delayed in getting to their destination or believe they are delayed. These journeys are usually familiar journeys, as in LFOTs participants were driving on a daily basis and followed routes that were part of their daily routine. The effect would rather be more evident in cases where the navigation support function was used in foreign or unfamiliar routes. Usually, people encounter such routes when they are on holiday and driving on holiday accounts for a small percentage of driving within a year.

The percentage of participants that declared that they perceived a slight or radical decrease in delays is significantly lower than the ones that declared no change, but statistically significant and higher than the ones that declare a slight increase.
Correlation to Background variables

The influence of three background factors was evaluated. The answers per LFOT for these factors are reported in Figure 10 to Figure 12. More drivers in Greece reported driving less than 10,000 km/year than the rest of LFOTs and more drivers in Sweden drive more than 20,000 km/year compared to the rest of LFOTs (Figure 10).

Figure 10. Driven Km per year distribution per LFOT site

As shown in Figure 11, more than 70% of participants in Italian LFOT reported to be experienced drivers than in other LFOT sites. Only in UK and Greek LFOT, some participants reported to be inexperienced drivers (very small percentages, though).
In Greek LFOT 1, almost 65% of driving is carried out in the city area which is something relevant to the main findings. Almost 40% of participants in Greek LFOT1 reported change in encountered delays compared to less than 10% in UK LFOT. Delays could be more common in urban environments. On the other hand, participants in the UK LFOT reported that they spent approximately 25% of their
driving time in city areas. The difference of 40% in time spent in urban areas between UK and Greek LFOT1 might be important for the 30% difference in reporting decrease in encountered delays. Perceived decrease is affected by perceived experience of delays. If no delays were encountered before and after the use of device, then probably no change is found because there is no actual change after all. These findings are similar to reported results for perceive avoidance of traffic jams (section 3.5). However, the statistical analysis performed for LFOTs excluded that this perception could depend on the considered background factors.

The interpretation could be that the function can provide small but significant benefits reducing delays, but they depend on specific situation characteristics experienced by the users each time.

**Traffic Information Support Function**

It was anticipated that traffic information will affect participants’ experience with delays. In particular, it was expected that drivers will experience fewer delays when using the traffic information function and report decrease in encountered delays when asked. Therefore, it was expected that traffic information would be important for avoiding delays.

Despite initial expectations, findings for traffic information function were similar to navigation support results, higher percentages of participants in Greek LFOT3 (more than 40%) reported decrease (although slight) in encountering delays than the other two LFOTs (almost 20% for the Swedish LFOT and less than 10% for the Finnish LFOT) as shown in Figure 13.

Still, the majority of participants in all three LFOTs reported no change to perceived delays because of using the traffic information function (Lowest: 55% of participants for Greece to highest: 84% of Finland). A marginal percentage of participants (from 0% to 4%) had a negative perception and declared a slight increase in their delays.
Figure 13. Perceived change in encountered delays because of using the traffic information function

For Finland and Sweden the percentage of participants that declared that they perceived a slight or radical decrease in their delays is significantly lower than the ones that declared no change, but statistically significant (major than zero) and higher than the ones that declared a slight increase.

For Greece the percentage of participants that declared that they perceived a slight or radical decrease in delays is not significantly lower than the ones that declared no change.

The influence of background variables was investigated. The distribution of answers based on responses across LFOTs for each factor is shown in Figure 14 to Figure 16. At least 50% of drivers from the Northern community (Finnish and Swedish LFOTs) drive more than 20,000 km per year. On the contrary, more than 70% of drivers in the Greek LFOT3 drive less than 10,000 km per year.
Figure 14. Distribution of reported km driven per year for LFOTs

Distribution based on reported driving experience is not very different across sites. Less than 40% of drivers reported that they are experienced drivers across all sites.

Figure 15. Distribution of reported driving experience for LFOTs

Probably drivers from the Greek LFOT3, drive less than 10,000 km per year because they spent more time driving within the city area. Athens is a large metropolitan city with more than 5 million inhabitants and serious congestion.
problems. Expectantly, more drivers in the Greek LFOT reported decrease in encountered delays because probably that was the case.

![Figure 16. Distribution of road types per LFOT](image)

For all performed analyses, it was excluded that any change in perceived delays could depend on the **background factors**.

### 3.2.3. Discussion and Conclusions

Both Navigation and Traffic Information support have the potential to reduce delays. Certainly the use of functions did not increase delays as the number of users who reported decrease surpassed those reporting increase. Slight decrease in encountered delays was experienced (perceived) by a significant minority of users, as the majority perceived no change. The percentage of participants perceiving the benefit varies from 6% in UK to 40% in Greece. This is reasonable because other factors affecting delays are also crucial. Avoidance of delays largely depends on the specific road and traffic situation driven by the users. In many cases, due to the physical structure of the road network, alternative roads are not available. Usually, drivers in their daily commuting routine are generally aware of the traffic conditions they encounter and they know the best road and the “backup” alternatives. Considerations for commuting journeys should be made in future potential functions (i.e. functions that are useful for common journeys and not always when venturing on to unfamiliar roads). These new functions foster a future perspective for cooperative systems and traffic flow regulation algorithms able to provide very reliable ad hoc routes to each vehicle with accurate trip time.
estimation. Emphasis should be placed on personalised daily predictions for commuters in highly congested areas.

3.3. Speed variations and exceedances

Besides the indicators like velocity profiles, traffic density, travel time and throughput another important measurement is average speed for the validation of the efficiency of a traffic network. The higher the average speed the more efficient is the traffic network. In this chapter, the influence of the TeleFOT functions on this measurement is presented.

**EFF-H3.1 The vehicle speeds in the network are likely to increase/decrease (when device is used compared to when device is not used)**

3.3.1. Methods

The methodology which is used to evaluate the influence of a pre-defined function on the speed distribution in a traffic network by means of the micro-simulation tool PELOPS is described in this section. PELOPS consists of three models; which are the driver model, the vehicle model and the environment model. The models themselves are described in D4.5.2.

Two steps must be considered in order to use PELOPS as a simulation tool for traffic efficiency with regards to the influence of functions. Firstly, there must be clear environmental boundary conditions and a driver model with standard parameters. This configuration serves as the baseline condition. Secondly, there must be the possibility to create the function which should be evaluated in PELOPS in terms of influence on traffic flow. The traffic flow simulation can be executed only if these steps are possible with the available data.

If the data and the results of the data analysis include the necessary data described above, a traffic flow simulation can be set up. Therefore, a certain route is created in the environment model and the amount of vehicles on the road is defined. For the baseline, the velocity of each vehicle in the network is recorded and can be evaluated afterwards. In the next step, the treatment condition must be implemented in PELOPS to simulate vehicles with a certain function. Therefore several parameters are available. Important driver parameters are:

- desired velocity,
- maximum possible deceleration,
- utilisation of vehicle acceleration,
- safety need,
- estimation ability,
- pedal sensitivity,
- speed limit compliance,
- compliance with an overtaking prohibition,
- maximum foot braking force,
- maximum pedal adjusting speed.

The challenge is to analyse those parameters in the baseline and in the treatment condition of the FOT and then to adapt these parameters in a manner that the driver behaviour in the treatment condition is more or less identical to that in the FOT. For intervening functions like ACC which take over a part of the vehicle control, the vehicle model can be adapted and the driver reacts to that. Informing functions do not actively control the car, so the only parameters which can be adapted are the driver model parameter.

After simulating both conditions (baseline and treatment) with different penetration rates of the vehicles, the velocity profiles of the vehicles can be compared. A higher average velocity of the cars represents an increase of efficiency and a better throughput.

### 3.3.2. Data analysis

The TeleFOT functions which can be modelled are all informing functions. Therefore, the only possibility to simulate the treatment condition is through adaptation of the driver model parameters.

Two TeleFOT functions are speed limit information and speed alert. The driver parameter speed limit compliance might be adaptable in order to create a treatment condition. Therefore, the behaviour of the subjects during baseline condition and treatment condition has been evaluated regarding speed limit compliance.

In the German DFOT a highly equipped vehicle is used in the FOT. All necessary information for evaluation of the speed limit compliance (ego-velocity, high-precision GPS position, speed limit on the road) is available in the vehicle. It is essential that the speed limit information on the map of the nomadic device is
identical with the real speed limit on the road. Since this is not the case on all chosen routes a filtering of road sections is necessary. An additional filtering must be performed to exclude those sections where no speed limit is set up like on some parts of the German motorway. Figure 17 shows an example of one entire route driven and the sections which have the potential for evaluation of the speed limit compliance. The blue sections are filtered out due to the reasons mentioned above. The red sections have no potential to contribute to the speed limit compliance of the subject because there is no speed limit on the road. The speed limits of the other coloured sections can be found in the legend. In this figure, it can be seen that only a minor part of the route can generally contribute to the analysis.

![Figure 17. Route 3 of German DFOT with speed limits](image)

**Figure 17. Route 3 of German DFOT with speed limits**

The vehicle speed, the position and the speed limit on the road from the map matching tool are compared to evaluate a possible speeding. Therefore, a speeding ratio is calculated. This speeding ratio is calculated by means of the following equation:

\[
\text{speeding ratio} = \frac{\text{current velocity}}{\text{current speed limit}}
\]
For each participant (within each route and condition) this speeding ratio was calculated and the configurations were compared regarding a change in drivers’ speed compliance. The calculation has already been described in D4.5.2. The boundary conditions (free flow, ego-velocity over a certain velocity threshold etc.) have been expanded since the first approach, but also with fewer restrictions and no statistical significant change could be found.

The other driver related parameters mentioned above are not suitable to model a TeleFOT function in a realistic way with PELOPS.

3.3.3. Discussion and Conclusions

There are two methods to evaluate the velocities in a traffic network. Either the velocity information of many vehicles on the road is available (e.g. they send their position and therewith their velocity to a central server) or by using a traffic flow simulation. In TeleFOT, the challenge was to evaluate the influence of a certain function on the driver’s behaviour. Therefore, a baseline condition and a treatment condition were necessary. Even if there would be a big fleet on the road which is equipped with data loggers, it is not possible to derive conclusions about the other vehicles in the network. The interaction between equipped cars and non-equipped cars cannot be considered in real traffic conditions. A traffic flow simulation is inevitable in this case. As mentioned in section 3.3.1, a traffic flow simulation needs at least two different conditions which should be compared. It is not feasible to model one of the TeleFOT functions for PELOPS, so that a traffic flow simulation could not be executed and the question if one of the TeleFOT function influences the speeds in the traffic network could not be answered.

In the national project INVENT (Hochstädtler, 2005) it could be shown that PELOPS is indeed a strong micro-simulation tool to simulate different functions with several penetration rates in the traffic network. Figure 18 and Figure 19 show velocity profiles for cars in a simulated traffic environment. The simulated distance is six kilometres (x-axis) for 900 seconds (y-axis). The colouring represents the average velocity at a certain distance and a certain time during
the simulation. If a traffic jam occurs, it is shown with red colour ($v = 0$).

Figure 18: Velocity profile without driver assistance system

The baseline condition in Figure 18 shows a traffic jam between 0 and 750 seconds. It starts at approx. 5.7 km at 0 s and moves to 3.5 km at 750 s before it dissolves. After 750 seconds, all vehicles are driving at an average velocity around 110 km/h without a traffic jam.

Figure 19: Velocity profile with ADAS (penetration rate: 20 %)
With the support of the simulated function and a penetration rate of at least 20%, it can be shown that the traffic jam starts to clear approx. 50 seconds earlier (cp. Figure 19). After approx. 700 seconds, all vehicles have a certain average driving speed without any traffic jam.

Similar information could have been produced for the TeleFOT functions if the modelling of those functions would have been achievable. PELOPS outputs all needs information such as velocity profiles, traffic density, average velocity, travel time and throughput for a simulated scenario.

3.4. Car following behaviour

Longitudinal driving behaviour shows great heterogeneity and therefore affects traffic flow. Differences in car following behaviour affect to some extent the distribution of vehicles in lanes leading to induced lane changes with more disturbances in traffic flow (Kernel and Klenov, 2004). On the other hand, low and stabilised headways increase traffic volume and therefore increase the efficiency for the traffic network. There are two important components for headway analysis; time and distance.

**EFF-H4.1 Headways are likely to increase/decrease (when device is used compared to when device is not used)**

**EFF-H6.1 Distance from the preceding vehicle is likely to increase/decrease (when device is used compared to when device is not used)**

3.4.1. Methods

It was anticipated that longitudinal behaviour would not be significantly affected by the use of nomadic devices. As availability of driving assistance systems are becoming abundant in the market, then the addition of nomadic devices was evaluated. In most cases, extrapolations are based on analysis of DFOT data as high resolution data are required for both reliable and valid inferences.

Two aspects of car following behaviour were investigated. Time and distance based metrics. Violation of safety margins (i.e. small following distances) could be interpreted as deteriorating driving behaviour with potentially negative safety consequences. Time headway is a reliable index of longitudinal behaviour fitting better an efficiency impact assessment than time to collision which is an index more appropriate for safety analysis. The DFOTs chosen for analysis are the ones that incorporated both support by the nomadic devices and ADAS. ADAS for the Greek and UK DFOTs were: Lane Departure Warning (LDW) and Forward Collision
Warning (FCW) systems. The German DFOT incorporated Adaptive Cruise Control (ACC), Lane Keep Assist (LKA), and Forward Collision Warning (FCW) systems.

Nonparametric statistics were applied in cases of violation of normality assumption or whenever the sample size was small to allow for parametric alternatives. Also, paired t tests were carried out. In rare cases, ANOVAs were performed (for example, in case of sample size was large and homogeneity of variance was not violated (e.g. Levene test performed; $F(1, 67) = 1.86$, $p = 0.177$)).

### 3.4.2. Results

**Time headway (sec)**

Time headway is defined as the distance to the lead vehicle (bumper to bumper) divided by the travel speed of the ego vehicle (i.e. own vehicle) (Östlund et al., 2004). Usually large values are discarded but in this case for the overall analysis larger values were included in certain conditions (for example, for calculation of time headway distributions during chosen routes).

- **Summary statistics**

  **Mean time headway**

The addition of the nomadic device and related functions did increase headway but not significantly ($p > .05$) in Greek DFOTs (1-3). The average increase in time headway for all DFOTs when compared to the pure baseline condition (free driving) was 8.85%. For the analysis of central tendency measures values higher than 5 seconds were excluded. Increase in headway was found for the condition with ADAS and then the difference stayed the same with the stepwise addition of navigation support, speed information and speed alert. It seems that increase in headway might result from ADAS but still it cannot be concluded that if functions were tested alone would not increase or decrease time headway.
Figure 20. Mean time headway (sec) in the Greek DFOTs

The UKDFOT2 utilised the Foot-LITE system which is a ‘Smart’ driving system which incorporates Green Driving Support (GDS) with safety features of Lane Departure Warning (LDW) and Forward Collision Warning (FCW). Foot-LITE provides the driver with feedback and information on “smart” driving behaviours in the vehicle, in real time via an integrated visual interface presented on a Smartphone ‘Smart’ driving system.

Similarly, time headway increased (Figure 21) with the addition of Foot-LITE system. A significant change in time headway was found (12.85%). The 0.28 sec increase because of the Green Driving Support and ADAS system was of statistical significance \((t (30)=4.41, p<.001)\). The reason for the significant difference (i.e. if it is an effect of the green driving support or the activated warnings) it was not possible to be revealed with this test design.

No significant differences were found for the German DFOT \((p>.05)\). Overall, mean time headways were much higher compared to other DFOTs because of lower traffic on the road segments in the selected test routes and the ACC longitudinal control. As shown in Figure 22, there are no differences among conditions. However, no pure baseline existed to compare these conditions to free driving with no nomadic device used. The findings are not clear about the effect of TeleFOT functions on mean headway in most sites. It appears that when functions are combined with ADAS, mean headway increases and increase in mean headway is not a positive result for efficiency. However, these results are not significant and differences are very small for any effects to be revealed.
Figure 21. Mean time headway (sec) in UKDFOT2

Figure 22. Mean time headway (sec) in German DFOT

A: NAV/SI/SA  B: ACC/FCW/LKA  C: combination of A+B

Standard deviation of time headway

Variations in longitudinal control might be of greater importance for efficiency assessment than mean values, as standard deviation is an index more robust to changes. Standard deviation (SD) of time headway was calculated for all DFOTs data.
Figure 23. Mean standard deviation for time headway in Greek DFOTs

Overall, related samples Friedman’s two-way ANOVA by ranks test was significant ($\chi^2(4)=15.3$, $p=.004$). Pair wise comparisons were carried out with Wilcoxon signed ranks test (Bonferroni adjustment). As the samples had a mean correlation of $r = 0.379$, then the Bonferroni correction was adjusted for the correlation from 0.005 to 0.012. The correction to Bonferroni adjustment was made in order to avoid making a Type II when trying to not make a Type I error. Stringent significance $\alpha$ values are retained because the number of pairwise comparisons is high, as variance in within subjects design accounts more for similarities than differences.

Significant differences were found for the following comparisons:

- Significant decrease (34.47%) of SD of time headway in DFOT2 when compared to the pure baseline condition (Baseline 1) ($z = -2.51$, $p=.012$).
- Significant decrease (26.39%) of SD of time headway in DFOT2 when compared to DFOT1 (navigation support) ($z = -2.51$, $p=.012$).
- Similarly, trend to significance was found for the pair wise comparison between DFOT2 and Baseline 2 (ADAS only with no TeleFOT functions) ($z=-2.38$, $p = .017$). The addition of navigation support and speed limit information decreased the standard deviation of time headway by 25%.

Interestingly, variation in time headway was lower for DFOT 2. The addition of speed limit information with navigation and ADAS was more effective than the addition of speed alert. An interpretation of this finding could lie to the fact that speed alert warning was either ignored by the users or lost as “noise”. Drivers
often asked the investigators for confirmation that the warning they heard was the speed alert. Variation in headways could directly affect the harmony of traffic flow.

Driver’s comments “carry” an important argument for designing the next generations of nomadic devices. Alerts should be prioritised and distinguishable so drivers can easily identify their purpose. Similarly, not many systems serving the same purpose should be included in a vehicle because they could end up distracting the driver rather than helping. For example, if many alerts are included, then some of them should be visual, others auditory and others haptic depending on their importance for the driving task and the response required by the driver.

Decrease in standard deviation of time headway was also found in UKDFOT2 (Figure 24). The application of the nomadic device significantly decreased the standard deviation of headway by 29.72% ($t$ (30) =1.994, $p$=.055).

![Figure 24. Mean standard deviation of Time Headway in UKDFOT](image)

**Figure 24. Mean standard deviation of Time Headway in UKDFOT**

Decrease in standard deviation was found for condition C compared to the other two conditions in the German DFOT. The differences were not of significance ($p$>.05) although the decrease in standard deviation in condition C was 9.84% and 10.59% compared to conditions B and A, respectively. The lowest variation in time headway was found in the condition with both bundles of functions and ADAS (Condition C). The combination of both ADAS and TeleFOT functions enhances the harmonisation of the network as fewer variations are found in
headway keeping for drivers using both systems and, therefore, has a positive effect on efficiency.

![Mean standard deviation of Time Headway in German DFOT](image)

**A**: NAV/SI/SA **B**: ACC/FCW/LKA **C**: combination of A+B

**Figure 25. Mean standard deviation of Time Headway in German DFOT**

**Minimum time headway**

The minimum time headway metric is directly linked to safety. Extremely low headways increase the probability of accidents that create numerous problems in traffic flow affecting the efficiency of a traffic network. Supposedly, if minimum headways are decreased, this is a positive finding for efficiency. Within the TeleFOT efficiency model though it was accepted that an efficient network should be safe. The generalisability of the effect to efficiency on real terms (i.e. for real traffic condition) would be more plausible if safety is considered.

No statistical differences were found for mean minimum time headway in Greek DFOTs ($p > .05$). However, the lowest minimum values were observed in the pure baseline condition (0.47±0.09) and the highest minimum values in DFOT3 with the bundle with all TeleFOT functions and ADAS (0.56±0.15).

No significant differences were found for minimum time headway in the UK DFOT study; however, a trend was revealed for decrease in the control condition ($t(30)=1.789, p = .089$). The Foot-LITE system increased the mean minimum time headway by 10.75%.
Similarly, no significant differences were found in the German DFOT ($p>.05$). Actually, minimum time headway values were very high compared to the other DFOTs. A few low mean minimum values were found for some of the participants but they were too few for analysis.

![Figure 26. Mean minimum time headway in Greek DFOTs](image)

- **Road types**

The second analysis level included stratification based on road types for the DFOTs where this information was available. Chosen road types were: urban, peri-urban and rural and motorway.

No differences were found among conditions in Greek DFOTs for the city area. The greatest (but not significant) difference found was between the pure baseline condition and DFOT3 (NAV/SI/SA) where a decrease of 6.43% in mean time headway was found. The functions slightly decreased time headway values but the differences is small within the city area. In addition, all values are above 2.4 seconds and therefore are far within safety limits.

In peri-urban and rural roads, significant differences were found between DFOT1 and Baseline 1 ($z=-22.87$, $p<.001$) and DFOT3 ($z=-28.2$, $p<.001$). In particular, mean time headway increased by 10.95% with the addition of navigation support but dropped 15.86% with the addition of speed alert. It is hypothesised that users were not so familiarised with these roads and therefore they paid more attention to the navigator resulting in more “loose” following. However, the addition of speed alert, decreased headway as constant longitudinal alert existed.
As mentioned earlier, there might be a potential conflict between these types of information as speed alert is more closely related to ADAS than IVIS and receiving both needs prioritisation by the driver.

For motorway analysis, significant differences were found. But in this case a significant increase from pure baseline to ADAS condition (14.95%) (Baseline 2) \( z = -19.31, p < .001 \) and significant decrease (18.2%) from baseline 2 to DFOT3 \( z = -24.49, p < .001 \) were found. Activation of FCW warnings were more frequent on motorways and probably the increase is related to increased warning activation. In addition, speed alert decreases time headway by stabilisation in speed variations.

The effect is similar to the ones revealed for the other road types but the increase was probably affected by the most prominent function in each road context. Navigation support was most needed on unfamiliar roads and ADAS warnings were more frequently activated on the motorway. The findings are potentially influenced by the need for “shift of focus” in each context. Drivers seem to prefer to prioritise based on context. In German DFOT no changes were found with regards road type between the three combinations, mainly because participants drove for most of the time on motorway.

For the UKDFOT2, no separate analysis per type of road was carried out as road segments of urban and interurban road were very small compared to the motorway.

- **Time headway distributions**

Percentage of time (%) spent with low time headway values was estimated in Greek DFOTs because of its importance for its effect on both traffic flow and volume. It is evident from Figure 27 that drivers in pure baseline condition spent almost three times more driving with dangerously low time headways (8.8%). No significant differences among the three DFOTs with the TeleFOT functions were found. Therefore, the addition of ADAS significantly decreases (5%) time spent with dangerous time headway values but the addition of the other functions did not significantly affect percentage of time spent with very low headways but also did not have a negative effect either.
Likewise, in UK DFOT drivers in the control condition spent three times more time with low time headway values compared to the treatment condition. A significant decrease (4.4.%) was attained in the condition with the 'Smart driving' support system \( t(30)= -4.061 , p=<.001 \).

---

**Figure 27. Time headway distribution for the whole route in Greek DFOTs**

---

**Figure 28. Percentage of time spent with time headway<1.5 sec in the UKDFOT2**
It is important to note, though, that warnings were activated for different thresholds in Greek DFOTs and in UK DFOT. In Greek DFOTs warnings were activated for headway below 1 second and in UK DFOT drivers received a warning when time headway was less than 1.5 seconds. Hence, this should be taken into consideration when attempting to interpret the findings from both sites. Values between 1 and 1.5 seconds were regarded as following behaviour in Greek DFOTs but they were regarded as dangerous car following behaviour in the UKDFOT. Hence, two different figures are provided for the UKDFOT. One for time spent driving with headway less than 1.5 seconds and above (dichotomous) (Figure 28) and one with the same categorisation applied in the Greek DFOTs (Figure 29).

**Figure 29. Time headway distribution for the whole route in UKDFOT2**

Participants spent significantly less time (24.76%; $z=-2.224$, $p=.026$) in category 2 and significantly more time (39.34%; $z=-2.289$, $p=.022$) in category 3 compared to the baseline condition. In addition, the difference for dangerously low THWY values (category 1; 0-1 seconds) is significant (55.12% decrease; $z(21)=-2.091$, $p=.037$). There were very few values greater than 5 seconds and their distribution did not differ between conditions. The difference for the lower THWY category (0-1) is less because the warning was set higher in the UKDFOT compared to the Greek DFOTs.
For the German DFOT the number of very small time headways was too limited to perform an analysis. Probably the combination of ADAS functions and the limited traffic did not create the conditions for close car following. The following graph presents the distributions for THWY values less than 5 seconds. In all three conditions, almost no car following was recorded (96% to 99% of time was spent with time headway values higher than 5 seconds). Driving with high speeds on motorway did not create any close car following conditions within the context of each condition tested. Higher percentage of time spent with low headways (2.7%) in condition C compared to the other two conditions was found for the German DFOT. This findings is contrary to the decrease found in Greek and UKDFOTs. However, the sample with low headways was small and with great variations among recordings so no statistical analysis was performed. The effect in increase is the result of one participant following very close for a very short time.

**Figure 30. Time headway distribution for values less than five seconds in German DFOT**

Further comparisons for mean and mean minimum time headway before and after the activation of ADAS warnings did not show any differences across the conditions. In addition, comparisons of size of differences for these metrics due to warning activation was not different among these conditions.
No effect of background variables (age, gender, driving experience, and driving style) was investigated on time headway. It was anticipated, that background factors will not be of significance for this indicator, mainly for two reasons. Firstly, the sample sizes are small for revealing such effects and secondly DFOTs are based on experimental designs where variables are more controlled, hence background effects are more difficult to be revealed.

**Space/distance headway (m)**

Distance or space headway \( (h_s) \) = difference in position between the front of a vehicle and the front of the next vehicle (in meters). Distance is a metric very closely related to time headway. The use of distance is a measure of driver's distance keeping behaviour.

**Methods**

The implemented method is the same as for time headway and is described in the previous section. Gap was not calculated as it is difficult to be estimate with already recorded variables (vehicles of different sizes and types could be in front of the instrumented vehicles and frontal video data were not available in all DFOTs). In approximation, the actual gap perceived by drivers was distance headway-(4.5 m). For example, if distance headway was 17 m, then the actual gap drivers saw having from the vehicle in front was approximately 12.5 m. But this is a very rough estimation.

The selected summary measures for distance headways are the same with the measures for time headway.

- **Summary statistics**

**Mean distance headway**

Greater mean distance was found in Greek DFOT Baseline 2 condition (23.9±5.6) when compared to the rest of Greek DFOTs (Figure 31). Significant decrease in mean distance was found in DFOT1 when compared to baseline 2 \( (z=-2.1, p = .036) \). Distance decreased on average by 16.9% in DFOTs with functions on (navigation, speed limit information, and speed alert) when compared to the ADAS only condition. Distance headway increased in ADAS condition by 11.85%. These differences are overall differences for the whole route for car following situations (i.e. time headway <3 seconds). The immediate effect of longitudinal control by ADAS is potentially “smoothened out” by the effect of nomadic devices. Distances get smaller with functions and, therefore, have a potential in affecting
density in heavier traffic situations. If lower distances are kept (within safety limits), then the effect for the road network might be positive. If distances are decreased, then density and road capacity might be increased. A road network with increased capacity is more efficient.

![Mean distance headway (m) in Greek DFOTs](image)

**Figure 31. Mean distance headway (m) in Greek DFOTs**

Mean decrease in mean distance headway in FOOTLite condition (UKDFOT2) compared to control (9.16%) was not significant ($t(21) = 1.729, p=.09$). This result shows a trend which was further investigated through trend analysis ($\chi^2$ linear-by-linear association $= 4.346, p = .037$). The trend for distance to headway (m) to decrease in the treatment condition for the UKDFOT was significant.

Mean distance headway for the overall comparison in the German DFOT was found to be statistically significant ($\chi^2(2)=7, p=.03$). Bonferroni correction was further adjusted for the correlation among conditions ($r=0.739$) and a for pairwise comparisons was lowered to 0.038. Further comparisons (Bonferroni correction applied) revealed significant differences in mean distance between condition A and B (9.37%; $z=-2.299, p=.022$). A trend for comparison between A and C (7.65%; $z=-1.799, p=.072$) was found. No significance was found for the comparison between condition B and C ($p>.05$). Mean distance decreased for both B and C conditions when compared to A condition in the German DFOT (A: NAV/SI/SA, B: ACC/FCW/LKA, and C: combination of A+B). The addition of functions appears to increase efficiency as decreases mean distance.
Standard deviation of distance headway

In Greek DFOTs standard deviation decreased by 27.1% in the DFOT with speed limit information function and ADAS (DFOT2) compared to the other conditions. The combination of ADAS with speed information seemed more efficient than the combination with speed alert. As mentioned before, conflict of warnings could be the issue. Statistically significant decrease was found in variation in DFOT2 when compared with baseline 1 (\(z=-2.24, p=.025\)), baseline 2 (\(z=-2.51, p=.012\)). A trend was found for the comparison of DFOT 2 with DFOT1 (\(z=-1.82, p=.069\)).

![Graph showing standard deviation of distance headway](image)

**Figure 32. Mean standard deviation distance headway (m) in Greek DFOTs**

Standard deviation in distance headway decreased only 1.93% between control and treatment condition in UK and the difference was not significant \((p>.05)\). Similarly, standard deviation for distance headway did not differ significantly among conditions \((p>.05)\) in German DFOT.

Minimum distance headway

Minimum distances kept are both related to safety and efficiency. If minimum distances are dangerously small, accidents might occur and efficiency is indirectly affected. If minimum distances are small but safe, then capacity could increase. This inference is more meaningful for heavier traffic. No significant differences were found among conditions for mean minimum distance headway in all DFOTs \((p>.05)\).
In Greek DFOT2 (speed information with ADAS) and Baseline 2 (only ADAS) the mean differences in mean min distance headway compared to the rest of DFOTs and the pure baseline condition was almost half meter (Figure 33). However, these mean differences were not significant.

![Mean minimum distance headway in Greek DFOTs](image)

**Figure 33. Mean minimum distance headway in Greek DFOTs**

Likewise, no significant differences were found in the German DFOT but a trend was found ($p = .09$). The trend was not significant with a chi-square (linear-by-linear association; $p = .06$). Lower mean minimum distance headway was found in condition A compared to condition B and C (average mean difference: 2.9 m). The use of the TeleFOT bundle of functions might not affect capacity as much as ADAS.

No statistically significant differences were found in minimum distances between the control and FOOTLite conditions in UKDFOT ($p > .05$). The difference is very small (i.e. 1.39 m greater in control condition) between conditions.

Distance headway is an interesting parameter to investigate with regards to driver’s perception of actual distances. Its sensitivity to road characteristics and speed variations make it a less reliable indicator.

- **Speed categories**

Stratification per road type was carried out because of the sensitivity of distance headway to speed. Further analysis was carried out for the key summary statistics (mean, SD, min) for 5 speed categories (<25, 25-50, 50-80, 80-110, 110-133).
>110 km/h). The investigation of differences among conditions for certain vehicle speed categories was carried out.

No significant differences in mean distance were found for all speed categories in UK and Greek DFOTs. Significant decrease in standard deviation of distance was found between conditions A and B for speed category 3 (i.e. between 50 and 80 km/h) (36.84% decrease in B; \( z = -2.028, p = .043 \)) in German DFOT. Therefore, variation in mean distance (i.e. standard deviation) decreased substantially in the bundle of functions condition compared to only ADAS condition (A).

Overall mean changes were calculated for all DFOTs. Changes for each DFOT were calculated as difference from their baseline. Pure baseline existed in Greek and UK DFOTs. In German DFOT, the baseline condition was with ADAS only. These calculation are for all DFOTs together and, hence, do not serve a statistical purpose. The reason for these estimations was to get an estimation of size and direction for overall change for each speed category. The main findings (mean/SD/min) were the following:

- As speed increased, mean overall change in distance decreased
- As speed increased, standard deviation decreased
- As speed increased, min distances decreased for speeds up to 50 km/h and greater than 110 km/h
- As speed increased, distances increased for speed between 50-110 km/h

### 3.4.3. Discussion and Conclusions

The main statistical significant findings were the following:

- 13% increase in time headway with green driving support and ADAS when compared with no functions in UKDFOT
- 35% decrease in standard deviation of time headway in navigation and speed information (DFOT2) and ADAS when compared to pure baseline in Greek DFOTs
- 27% decrease in standard deviation of time headway in navigation and speed information and ADAS(DFOT2) when compared to navigation support (DFOT1) in Greek DFOTs
- 30% decrease in standard deviation of time headway in green driving support and ADAS (DFOT2) when compared to navigation support (DFOT1) in Greek DFOTs
• Potential conflict between ADAS and speed alert. Speed alert is the only function which is not informative but alerting.
• The effect of ADAS and TeleFOT functions seems to be complementary with the exception of warnings/alerts
• 11% increase of mean time headway with navigation support and ADAS compared to pure baseline when driving in rural roads in Greek DFOTs
• 16% decrease of mean time headway with speed information and ADAS compared to pure baseline in rural roads in Greek DFOTs
• 15% decrease in standard deviation of time headway with ADAS compared to pure baseline (Greek DFOTs)
• 18% decrease in standard deviation of time headway with navigation support, speed information, alert and ADAS compared to pure baseline in Greek DFOTs
• 5% less time spent with dangerously small headways (<1 sec) in all DFOT conditions compared to pure baseline (Greek DFOTs)
• 4.4% less time spent with dangerously small headways (<1 sec) with green driving support and ADAS compared to control (UK DFOT)
• 17% significant decrease in mean distance with navigation support with ADAS compared to ADAS in Greek DFOTs
• 10% decrease in mean distance with navigation and speed information/alert compared to ADAS only (German DFOT)
• 27% decrease in standard deviation in distance in navigation support, speed information and ADAS conditions compared to all other conditions (pure baseline, ADAS, navigation support, navigation support with speed information/alert) in Greek DFOTs

Overall, the effect of the combination of ADAS and TeleFOT functions seems complementary and not contradictory. These findings show positive effects of these functions for the stability of the network and the potential harmonisation of traffic flow.

However, no differences were found in subjective assessment of longitudinal control because of using the TeleFOT functions in different LFOTs. This analysis is discussed in detail in Deliverable 4.4.3 “Safety Impact Assessment and Implications”. Differences in mean headways were not found in objective data analysis (with the exception of green driving support) but differences in variations were abundant in DFOTs. The difference between subjective and objective assessments might be the result of the following reasons:
• Different data sources (questionnaires vs. logged data) were used in analysis;
• Different sites were included (LFOTs vs. DFOTs);
• Longitudinal control from questionnaires is probably translated in “perceived gap”. Gap (front-rear distance) is a different indicator from time headway and distance headway (front –to- front distance);
• ADAS were included in DFOTs.

3.5. Avoidance of traffic jams

Traffic congestion significantly affects both the quality of life and the national economies and is considerably onerous as people cannot plan it. It affects choice of habitance, time it takes to get to work and it leads to wasted fuel (Cambridge Systematics, 2002). From the infrastructure viewpoint, the problem has been tackled by traffic operational improvements the last decades.

**EFF-H5.1 It is likely that traffic jams are avoided (when device is used compared to when device is not used)**

### 3.5.1. Methods

In this analysis, the interest is shifted towards exploring the potential effect of already used devices for either alleviating or burdening the driver. As diverse routes were followed (i.e. different networks) focus shifted to what participants believe is the effect of the system. On the other hand, the accessibility aspect of TeleFOT efficiency model was best accommodated by subjective assessments as it links drivers’ own estimations of efficiency to efficiency within TeleFOT.

Participants used the nomadic device for a long period of time for their own daily driving needs and, therefore, perceived effect is based on repeated occasions and not just several and/or isolated occasions.

The investigation of EFF-H5.1 hypothesis was based on the collected User Uptake post traffic information questionnaires filled in by the relevant LFOT participants. Only LFOTs with traffic information were selected for this analysis.

Participants were asked whether they thought ‘getting stuck in traffic jams’ during driving changed due to their access to the navigation support system. The participants were asked to rank likely changes in perception of getting stuck in traffic jams on a 5-point scale where ‘1’ represents radical decrease (equivalent to traffic jams avoidance was perceived as increased due to access to the specific
function) and ‘5’ represents radical increase (equivalent to traffic jams avoidance was perceived as decreased due to access to the specific function).

The research question is applicable to the dynamic navigation support and the traffic information functions. Moreover, for all test-sites, participants were only included in the analysis if they completed the after questionnaires within the LFOTs. This led to the exclusion of a number of participants.

It was expected that the introduction of the devices would increase participants’ perception of traffic jams avoidance as the devices would provide the participants the relevant information.

Data considerations

For this hypothesis, the traffic information functions provided by the system in the Finish LFOT, the Swedish LFOT2 and LFOT4, the Greek LFOT3 and the Spanish LFOT2 (in Madrid) can be treated independently. Navigation support, green driving support and speed info/alert are expected to have no effect and hence any effect observed could potentially be attributed to Traffic Info only.

Analysis of changes in the perception of traffic jams avoidance following use of a Traffic Information system could be analysed at three test-sites (Finland, Greece and Sweden). These are as shown in the following figures (Figures 23-26).

Participants were asked after the completion of the LFOT whether they thought their ‘getting stuck in traffic jams’ during driving changed due to their access to the traffic information system. As mentioned above, participants were asked to rank the likely changes in perception of getting stuck in traffic jams on a 5-point scale where ‘1’ represents radical decrease in perceived getting stuck in traffic jams (equivalent to traffic jams avoidance was perceived as increased due to access to the specific function) and ‘5’ represents radical increase (equivalent to traffic jams avoidance was perceived as decreased due to access to the specific function). Data were available from relevant LFOTs performed in Finland, Sweden, and Greece.

3.5.2. Results

Results are presented per LFOT included in this analysis with traffic information function.

The vast majority of participants in Swedish LFOT2 reported that they thought that the traffic information service did not change the amount of traffic jams they
encountered (44 out of 68 participants, equivalent to 64.71%). Almost 34% of participants reported slight decrease in encountering traffic jams when using the traffic information function (23 out of 77 participants). Only one participant reported that the access to the function resulted to a radical decrease in encountering traffic jams.

Figure 34. Perception of change in traffic jams avoidance (Sweden; LFOT2)

The majority of participants in Swedish LFOT4 reported that the use of traffic information service made no change to encountering traffic jams (24 out of 43 participants, equivalent to 55.8%). 27% of users reported slight decrease in encountered traffic jams (16 out of 43 participants), while one participant reported that the access to the function resulted to a radical decrease of getting stuck to traffic jams (1.69%) and two participants reported that the access to the function resulted to a slight increase on encountering traffic jams (3.39%).

10% of participants (8 out of 77) reported slight decrease in getting stuck in traffic jams and the majority (40%) reported no change in the Finnish LFOT, while the rest of participants did not answer this question (38 out of 77).

The majority of the participants of the Spanish LFOT2 reported that the dynamic navigation/traffic information service made no changes to encountering traffic jams (19 out of 35 participants, equivalent to 54.29%), however the rest reported that the traffic information service resulted in a perceived slightly decrease in perceived getting stuck in traffic jams (16 out of 35 participants...
equivalent to 45.71%). No participant reported an increase in getting stuck to traffic jams due to access to the function.

Figure 35. Perception of change in traffic jams avoidance (Swedish LFOT4)

Figure 36. Perception of change in traffic jams avoidance (Finnish LFOT)
More than half of participants in the Greek LFOT3 thought that the traffic information function slightly decreased their perceived encounters with jams (41 out of 77 participants equivalent to 53.25%) or that it made no changes to their getting stuck in traffic jams (32 out of 77 participants, equivalent to 41.56%), while three participants reported that the access to the function resulted to a radical decrease in encountering traffic jams (3.9%) and one participant reported that the access to the function resulted to a slight increase in getting stuck in traffic jams (1.3%).

Figure 37. Perception of change in traffic jams avoidance (Spanish LFOT2)

Figure 38. Perception of change in traffic jams avoidance (Greek LFOT3)
Correlation to Background variables

Duration changes were analysed by **exposure** (in the sense that if users are more exposed, then there is greater possibility to get stuck in traffic jams), **familiarity of functions** (familiarity with traffic information systems and reported changes in getting stuck in traffic jams) and **opinions** (participants’ responses based on the degree they agree with specific statements on traffic congestion). The analyses were made function specific (traffic information), and the groups that had a certain change (decrease/increase) in feeling of traffic jams avoidance were compared to those who had no change at all.

Chi-square test was used to determine if there was a connection between exposure, previous experience of the function and the function use during the trial, and participants’ opinions on traffic congestion. (Cell frequencies were not in all cases sufficient related to test assumptions, but the test was carried out regardless).

**Exposure** was based on annual mileage. Total annual driving kilometres were classified as less than 10000, 10001-20000, 20001-30000, 30001-50000 and more than 50001.

No statistical difference (p>.05) was found among participants in any of the LFOTs based on annual driving mileage. Cell distribution is not uniform as most drivers fall into less than 20,000 km/year categories. As highlighted in Table 13, a trend was found for Spanish LFOT (p=.080).

**Table 13. Chi-square test results between change in traffic jams avoidance and total annual kilometers**

<table>
<thead>
<tr>
<th>LFOT</th>
<th>functions</th>
<th>N</th>
<th>Chi-square</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>FIN-LFOT</td>
<td>TI</td>
<td>64</td>
<td>2.446</td>
<td>0.654</td>
</tr>
<tr>
<td>SWE-LFOT2</td>
<td>TI</td>
<td>68</td>
<td>5.645</td>
<td>0.227</td>
</tr>
<tr>
<td>SWE-LFOT4</td>
<td>TI</td>
<td>43</td>
<td>5.536</td>
<td>0.853</td>
</tr>
<tr>
<td>ESP-LFOT2</td>
<td>TI</td>
<td>35</td>
<td>8.326</td>
<td>0.080</td>
</tr>
<tr>
<td>GR-LFOT3</td>
<td>TI</td>
<td>117</td>
<td>8.286</td>
<td>0.406</td>
</tr>
</tbody>
</table>
The effect of road types driven was investigated by classifying the road types to city, highway/motorway, and rural. Classification for road types was made by dividing the questionnaire data in two classes, less than 50% (0) and more than 50% (1). No statistical significant effect of road type was revealed (p>.05).

**Table 14. Chi-square test results between change in traffic jams avoidance and road types driven**

<table>
<thead>
<tr>
<th>LFOT</th>
<th>functions</th>
<th>N</th>
<th>Chi-square</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>City</td>
<td>Highway/Motorway</td>
<td>Rural</td>
</tr>
<tr>
<td>FIN-LFOT</td>
<td>TI</td>
<td>64</td>
<td>0.068</td>
<td>2.110</td>
</tr>
<tr>
<td>SWE-LFOT2</td>
<td>TI</td>
<td>68</td>
<td>1.169</td>
<td>0.032</td>
</tr>
<tr>
<td>SWE-LFOT4</td>
<td>TI</td>
<td>42</td>
<td>1.253</td>
<td>3.264</td>
</tr>
<tr>
<td>ESP-LFOT2</td>
<td>TI</td>
<td>35</td>
<td>1.446</td>
<td>0.033</td>
</tr>
<tr>
<td>GR-LFOT3</td>
<td>TI</td>
<td>117</td>
<td>1.628</td>
<td>0.509</td>
</tr>
</tbody>
</table>

**Familiarity with traffic information** was investigated with four alternatives: no experience on function, some previous information on function but no use experience, some use experience and considerable use experience. **Familiarity with traffic information in Greek LFOTs was shown to be of importance for drivers who had reported change in avoidance of traffic jams** (p=.004).

**Previous access to traffic information** function was determined with two alternatives: no previous access to function (N), and previous access to function (Y). Similar to the previous finding (i.e. familiarity with TI function), **previous access was an important factor for reporting change in traffic jams avoidance** (p=.009) in Greek LFOT3.
Table 15. Chi-square test results between change in traffic jams avoidance and previous familiarity with function.

<table>
<thead>
<tr>
<th>LFOT</th>
<th>functions</th>
<th>N</th>
<th>Chi-square</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>FIN-LFOT</td>
<td>TI</td>
<td>64</td>
<td>6.632</td>
<td>0.085</td>
</tr>
<tr>
<td>SWE-LFOT2</td>
<td>TI</td>
<td>68</td>
<td>4.350</td>
<td>0.226</td>
</tr>
<tr>
<td>SWE-LFOT4</td>
<td>TI</td>
<td>43</td>
<td>4.005</td>
<td>0.676</td>
</tr>
<tr>
<td>ESP-LFOT2</td>
<td>TI</td>
<td>35</td>
<td>7.857</td>
<td>0.097</td>
</tr>
<tr>
<td>GR-LFOT3</td>
<td>TI</td>
<td>117</td>
<td>19.106</td>
<td>0.004</td>
</tr>
</tbody>
</table>

Table 16. Chi-square test results between change in traffic jams avoidance and previous access to function.

<table>
<thead>
<tr>
<th>LFOT</th>
<th>functions</th>
<th>N</th>
<th>Chi-square</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>FIN-LFOT</td>
<td>TI</td>
<td>64</td>
<td>3.595</td>
<td>0.079</td>
</tr>
<tr>
<td>SWE-LFOT2</td>
<td>TI</td>
<td>68</td>
<td>0.971</td>
<td>0.324</td>
</tr>
<tr>
<td>SWE-LFOT4</td>
<td>TI</td>
<td>43</td>
<td>2.720</td>
<td>0.606</td>
</tr>
<tr>
<td>ESP-LFOT2</td>
<td>TI</td>
<td>35</td>
<td>4.384</td>
<td>0.112</td>
</tr>
<tr>
<td>GR-LFOT3</td>
<td>TI</td>
<td>117</td>
<td>9.325</td>
<td>0.009</td>
</tr>
</tbody>
</table>

**Opinions** were given as agreements to statements with five options: with strongly disagree (SD), disagree (D), neither agree nor disagree (N), agree (A) or strongly agree (SA). Opinions express attitudes and the relation of their attitudes is important for their perception of the usefulness of the traffic information function. Attitudes require longer periods of use/exposure to a situation in order for change to happen. Attitudes and beliefs are quite resistant to change.

Same as for previous related factors, users who reported change mentioned that they believe that traffic congestion is a serious global problem (positive environmental friendly attitude) ($p<.001$) in Greek LFOT3.
**Opinion 1:** Responses on the degree the respondents agree with the statement: ‘Traffic congestion is a serious problem from an environmental point of view’

Table 17. Chi-square test results between change in traffic jams avoidance and opinion 1.

<table>
<thead>
<tr>
<th>LFOT functions</th>
<th>N</th>
<th>Chi-square</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>FIN-LFOT TI</td>
<td>64</td>
<td>3.137</td>
<td>0.371</td>
</tr>
<tr>
<td>SWE-LFOT2 TI</td>
<td>68</td>
<td>1.362</td>
<td>0.506</td>
</tr>
<tr>
<td>SWE-LFOT4 TI</td>
<td>43</td>
<td>9.500</td>
<td>0.485</td>
</tr>
<tr>
<td>ESP-LFOT2 TI</td>
<td>35</td>
<td>3.300</td>
<td>0.509</td>
</tr>
<tr>
<td>GR-LFOT3 TI</td>
<td>117</td>
<td>126.640</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

**Opinion 2:** Responses on the degree the respondents agree with the statement: ‘I would reduce my car use if traffic congestion increased further’

Similarly, environmentally friendly attitude was evident in drivers who reported change in avoided traffic jams because of using the traffic information function (Greek LFOT3; p<.001).

Table 18. Chi-square test results between change in traffic jams avoidance and opinion 2.

<table>
<thead>
<tr>
<th>LFOT functions</th>
<th>N</th>
<th>Chi-square</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>FIN-LFOT TI</td>
<td>64</td>
<td>7.282</td>
<td>0.122</td>
</tr>
<tr>
<td>SWE-LFOT2 TI</td>
<td>68</td>
<td>1.924</td>
<td>0.588</td>
</tr>
<tr>
<td>SWE-LFOT4 TI</td>
<td>43</td>
<td>7.665</td>
<td>0.662</td>
</tr>
<tr>
<td>ESP-LFOT2 TI</td>
<td>35</td>
<td>4.036</td>
<td>0.544</td>
</tr>
<tr>
<td>GR-LFOT3 TI</td>
<td>117</td>
<td>117.919</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>
Opinion 3: Responses on the degree the respondents agree with the statement: ‘New technology plays an important role in solving the problem of traffic congestion’

Users who were more positive towards New Technologies reported change in how many traffic jams they avoided. Users who are more positive towards New Technologies they tend to use technologies more in their everyday life. Potentially they are the users who are more likely to use these functions (or new functions) in different nomadic devices (e.g. smart phones, tablets, etc.).

Table 19. Chi-square test results between change in traffic jams avoidance and opinion 3.

<table>
<thead>
<tr>
<th>LFOT</th>
<th>functions</th>
<th>N</th>
<th>Chi-square</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>FIN-LFOT</td>
<td>TI</td>
<td>64</td>
<td>2.610</td>
<td>0.456</td>
</tr>
<tr>
<td>SWE-LFOT2</td>
<td>TI</td>
<td>68</td>
<td>0.973</td>
<td>0.615</td>
</tr>
<tr>
<td>SWE-LFOT4</td>
<td>TI</td>
<td>43</td>
<td>4.443</td>
<td>0.617</td>
</tr>
<tr>
<td>ESP-LFOT2</td>
<td>TI</td>
<td>35</td>
<td>2.156</td>
<td>0.827</td>
</tr>
<tr>
<td>GR-LFOT3</td>
<td>TI</td>
<td>117</td>
<td>117.995</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

3.5.3. Discussion and Conclusions

On the whole, FOT participants were relatively positive about the impact that nomadic devices functionalities had on their perceptions of traffic jam avoidance.

Change that was not reported could be perceived as change happening but not reported (false rejection) or change not happening and not reported (true acceptance). If traffic information function did change encountered traffic jams because drivers followed alternative routes that would be more evident in parts of Europe with higher congestion issues such as Athens. This is agreement with presented percentages in

Figure 39. Percentages might be higher in other sites because not many traffic jams were encountered after all for this function to be as useful as need for the effect to be revealed.
Most users reported that the traffic information function made no change. One third of users, though, said that traffic information function slightly decreased their getting stuck in traffic jams. Some participants did indicate that due to access to the traffic information service, their feeling of getting stuck in traffic jams was decreased radically.

Other factors, like familiarity with the traffic function, positive attitude towards implementation of New Technologies, and an overall environmental friendly attitude seem to play a role in perceiving change in avoidance of traffic jams.

Overall, hardly any of the participants responded that they believed the device would have a radical increase on their feeling of getting stuck in traffic jams, although some participants did indicate that the devices would slightly increase their perceived getting stuck in traffic jams.

![Figure 39. Perception of change in traffic jams avoidance for all LFOTs](image)

**Figure 39. Perception of change in traffic jams avoidance for all LFOTs**
4. IMPLICATIONS FOR EFFICIENCY

The FESTA project developed recommendations (www.its.leeds.ac.uk/festa) for furthering research, those propose certain topics for investigating implications. Not all implications are discussed within this deliverable as they are not relevant to the work carried out within TeleFOT or are investigated in other WPs (for example, business models were developed in WP4.7). Implications that might be relevant for efficiency are highlighted in blue (Figure 40).

![Figure 40. FESTA recommendations for implications for impact areas](image)

However, potential implications are primarily addressed based on the TeleFOT efficiency model and discussed based on the importance of efficiency impacts for each function or bundles of functions (based on available significant findings). Since, no statistical differences were found in order for simulation to be performed with different penetration rates for speeding and speed variations, implications were not investigated based on penetration rates for these functions.

The effect of certain functions is primary, others secondary and others negative or not clear.

The colours used for depicting impact are three; blue for positive, light blue for slightly positive, red for negative impact, grey for conflicting impact. The rest of colours are the colours depicting the different aspects of the TeleFOT efficiency model (Figure 1) and do not carry any meaning related to impact.
4.1. Navigation

Navigation support function affected duration for identical pairs of journeys in LFOTs. In Spanish LFOT (Valladolid site) one third decrease in variations in journey duration). In Spain, speed limit/alert was tested in bundle with navigation. In Greece (LFOT1) no difference was found for navigation alone when compared to pure baseline. Navigation support could decrease duration by providing alternative routes (e.g. provided “fastest” or “shortest” route) and alleviating existing volume (volume re-distribution). Navigation alone did not affect how drivers perceived avoidance of traffic jams and delays per se. Drivers reported slightly less delays when using navigation support in conjunction with dynamic traffic information. It should be noted though that the difference was slight and variant (i.e. variation across sites was observed).

It appears to be important for increasing efficiency. The choice of other peri-urban roads or rural roads, for example because of navigation support could potentially affect efficiency because of re-distribution of traffic volume to smaller roads and subsequent avoidance of traffic jams and delays. Route choice was investigated in mobility impact assessment and significant changes in road distributions were found. Navigation stands out as the function that seems to have the largest impact, followed by traffic information. Also green driving support indicates that participants have changed their route preferences.

This is a finding relevant to another impact area but duration is inter-connected across impact assessment areas and also intra-connected with several factors (i.e. duration is affected by both route choice, speed choice, etc.). In addition to changes in road type distribution, impacts on distance indicate use of new routes. The same applies to duration, as none of the functions had an impact on the traffic situation; if a driver makes journeys faster than during the baseline, it is likely that he/she has found a better route. Here, slight impacts on distance were reported by many participants. Therefore the same functions that affected distance driven, i.e. navigation, green driving support and traffic information, can be assumed to impact route choice also. Navigation stands out as the function that seems to have the greatest impact.

Decrease in time spent with dangerously small headways (minimisation in possible disruptions in the network) are of importance for efficiency. Navigation support was found to affect standard deviation of time headway and decrease variation (positive impact depicted with blue in Figure 41). Decrease in driving
time with lower and dangerous headways is positive from the road operator’s and the driver’s point of view (positive impact depicted with blue in Figure 41). In other words, this decrease can be good from road operator point of view as too small headways lead to accidents. From driver perspective, spending less time driving with small headways causes less stress and requires less concentration.

Decrease in variation in headway could lead to increased stability of the network and more harmonised flow, but increased stability not necessarily offers increased capacity and volume. A more harmonised traffic flow is positive for traffic efficiency (positive impact depicted with blue in Figure 41).

![Diagram showing Efficiency, Traffic flow, Traffic volume, Accessibility, Travel time, Time/Distance Headway, Delays, Speed, Traffic jams, Delays, and Time/Distance headway]

**Figure 41. Implications of navigation support for efficiency (positive impacts are highlighted with blue)**

It appears to be very important for the next few years that users are informed and trained about using navigation support systems for more efficient route
planning. Drivers are familiar with shortest and fastest routes but not with efficient routes.

4.2. Traffic information

Traffic information affected journey duration significantly with least decrease at 10%.

Avoidance of traffic jams and delays were not affected by traffic information as reported by most participants. Nevertheless, one third of drivers mentioned decrease in encountered delays and traffic jams because of using traffic information. The use of system was perceived as effective in assisting drivers to avoid traffic jams in large urban areas (i.e. Athens). This perceived impact diminished in other tests sites characterised with fewer traffic jams and congestion. Therefore the effect was perceived probably most in highly congested areas.

Traffic information is potentially more useful and needed more in large city (urban) areas with increased potential for exposure to traffic jams and, subsequently, delays. Both delay and traffic jam avoidance was based on drivers own feeling (i.e. perceived) of avoiding or not encountering them as these were aftermarket products and their efficiency (as devices) has probably been tested before market deployment and penetration.

Maybe the best testing location for revealing differences would be a pilot site with such characteristics (large city area with congestion issues, many vehicles per inhabitant, etc.). Evidently, decreases were found in Greek LFOTs where pilots were carried out for long periods of time within Attiki region. The gain from using a navigation and traffic information system within the city was more obvious because of increased exposure. If you encounter more jams or delays on a daily basis, then you could probably easier “spot the change” when it occurs.

As traffic information was the primary function for efficiency then three guidelines were derived from the main findings and are reflecting the main implications. Two of these guidelines could be proposed for the advantage of adding traffic information in existing navigation systems for potential diffusion in future policies and new system’s design.
To summarise, traffic information has a **primary positive effect** in travel duration, in headway variations, decreases dangerous car following and affects perceived change in delays and traffic jams (small change and great variations among LFOTs and not included in efficiency model as an effect).
GLP\textsuperscript{10}: The addition of traffic information in generic navigation support could decrease journey duration up to 10\%.

GLT\textsuperscript{11}: The potential effect of using dynamic traffic information could decrease duration of journeys and potentially increase efficiency for roads and drivers. These results should be first translated before disseminated to user. Then finding should be communicated to public by, firstly, training people on what traffic information is for traffic efficiency and for drivers and then how the use of traffic information might affect both their driving experience and behaviour (e.g. stress, comfort, satisfaction).

GLT\textsuperscript{12}: The use of traffic information function in your device could help you save travelling time in your daily commuting.

4.3. Speed limit information/alert

Speed limit information and alert seems to affect journey duration less than traffic information. Significant decreases were found in LFOTs with pure baselines and not in all of them. Therefore, these functions decrease journey only when compared to no function. Speed limit information/alert was not anticipated to have any effect in avoidance of traffic jams and delays as their functionality do not serve such purpose.

Speed limit and alert have a secondary effect in efficiency. The indirect effect because of longitudinal control in speed variations and exceedances was not evident in these studies. Therefore, the implications for efficiency were not found as initially expected. The result could be because of both not affecting longitudinal control to such extent that significance was attained but also because of the combination of functions. This is not necessarily a negative finding for efficiency. Speed limit information and alert affect time spent with very low time headways when combined with ADAS. Drivers spent almost half less time with very low time headways when using the TeleFOT functions and ADAS. Decrease of accidents could be attained and the stability of traffic flow to be less affected. This finding has a twofold advantage, it affects both safety and efficiency.

\textsuperscript{10} Guideline for policy makers
\textsuperscript{11} Guideline for public information & training
\textsuperscript{12} Guideline for users
In a nutshell, speed variations were not found significant in DFOT comparisons between ADAS and bundle of functions’ condition. Speed variations as expression of longitudinal control could be controlled by ADAS. However, speed limit/speed alert function did decrease headway variation and time spent with dangerously small headway in DFOTs (significant from baseline) at about 16% more than ADAS. Speed limit information and alert contribute further to longitudinal control already affected by ADAS and, thus, decreasing even further variations in headway. Overall, speed limit information/speed alert appears to hold secondary role for traffic efficiency.

Figure 43. Implications of speed limit/alert for efficiency (positive impacts are highlighted with blue)
4.4. Green driving support

Green driving support increases journey duration by up to 18%. When green driving is bundled up with speed limit information/alert then the increase is greater than when it is used with traffic information. Green driving support was not anticipated to affect avoidance of traffic jams and delays. Green driving support and traffic information appear to be more related (primary) to efficiency compared to speed information and speed alert (secondary). The reason for negative effect of green driving support might lie in the fact that this system did not include navigation support.

The bundle with both Green driving support and ADAS significantly increased also time headway (13%) in UKDFOT. Increase in mean headway – based on these findings - cannot be attributed only to ADAS or green driving support but only to both of them. Increase in headways would decrease volume and capacity in heavier traffic with high penetration rates for these vehicles (i.e. vehicles with green driving support and ADAS).

Therefore, this is a negative effect for efficiency. On the other hand, decrease in time spent with very small and dangerous headways is positive for both safety and efficiency. This effect of green driving support is indirectly positive for efficiency. It should be borne in mind, though, that the primary impact of green driving should be on environment and not efficiency.
Figure 44. Implications of green driving support for efficiency (slightly positive impacts are highlighted with lighter blue, negative with red, and conflicting with grey)
4.5. Focus groups with stakeholders

Two focus groups were carried out with representatives from stakeholders related to macro-operation, organisation, and management of traffic infrastructure and road networks. Two focus groups (N=6) were conducted for exploring the impact on traffic efficiency from the road operators’ and traffic management side.

Representatives from the following areas took part:

- Traffic management
- Emergency services’ management
- Infrastructure contractor
- Traffic operator

The main topics discussed were the potential impact of nomadic devices and their functions on traffic efficiency from their perspective for the measurements and estimations made within TeleFOT.

The outcomes are topics for implications for efficiency and not results. They are included in this deliverable mostly as “food for thought” for future development of use cases and scenarios (i.e. input for user needs and preferences for traffic managers and operators) for evaluation of nomadic devices for traffic macro-management and operation.

The main outcomes are resumed as follows:

- Duration is affected by route change. Route choice also would affect preferred type of network and roads, especially for larger cities.
- Navigation support should be bundled with dynamic traffic information if any effect in efficiency is expected.
- The effect of TI function should be evaluated in more complex systems (i.e. communication with infrastructure operators).
- If certain functions were activated for certain periods of time or certain km driven (communication/transmission of information to operators), then the latter could provide an estimation of use and effect on the network based on geometrical road characteristics and road capacity. These outcomes could then be compared to characteristics of non-equipped vehicles.

On the other hand, the speed limit information and alert functions were attributed as secondary as their effect potentially contributes to the harmonisation of the road network and inherent fluctuations would be unavoidable and application of different penetration rates would not lead to reliable information.
These outcomes are briefly mentioned in this document as they were not initially anticipated to be carried out but they fall in place with the outcomes from the evaluation within TeleFOT.

4.6. Societal impacts

Traffic information seems to be of primary importance for efficiency and its use will increase efficiency. Increased efficiency is beneficial for the society for several reasons. It is beneficial for the driver and the traffic network (e.g. traffic operators, managers, etc.).

The knowledge and “know-how” derived by these studies for different impact areas could be distilled into knowledge for adaptation of these functions to other road users. Such an effort could increase even more efficiency and augment the positive effect for society as more stakeholder groups will directly benefit from these functions.

The effect is indirectly beneficial for other road users (e.g. riders, pedestrians, cyclists). In the future, the effect could be also direct for other road users and especially for the aforementioned vulnerable road users, if these functions are adjusted for these groups. Within SAFERIDER European project (www.saferider-eu.org), technologies were developed for adjusting ADAS and IVIS for Power-To-Wheelers (ARAS and OBIS, respectively\(^\text{13}\)). The adaptation of technologies is a current fact, and this could also happen for integrated functions in nomadic devices.

Two realistic limitations apply. Firstly, these functions have been already replaced by more advanced and more complex functions (e.g. providing more information to the driver about Points of Interest (POIs), etc.). Secondly, advancements in New Technologies are radical and sometimes users’ requirements are not identified in time.

Finally, society certainly gains from increased efficiency but overall gain is difficult to be estimated with such diversity in integrated functions and nomadic devices that are replaced by new ones every few months. Their evaluation methodologies should be adjusted to rapid growths not only from a cost-benefit perspective but

---

\(^{13}\) ARAS: Advanced Riding Assistance System
OBIS: On-Board Information System
also from user needs’ perspective (e.g. new attitude in development and deployment of smart phones in creating consumers’ needs not there before).

Scaling up of findings (Chapter 5) is an effort to bring these findings for “use” on a European level with limitations and restrictions that apply based on FOTs conducted.
5. SCALING UP TO EUROPEAN LEVEL

The European Union has launched major initiatives to overcome the slow and fragmented uptake and deployment of ITS in road transport.

The European Commission’s ITS Action Plan and — in the form of the ITS Directive — dedicated EU legislation on ITS together constitute a concerted policy framework to boost ITS across Europe. With these two complementary elements in place, the roadmap is now clearly set and the tools are available to bring ITS deployment into a new era where integrated, interoperable systems and seamless transport services become the norm for Europe’s road transport system.

European projects are directed towards the importance of scaling up approaches for efficient applicability of research findings to policies and directives (e.g. ARMITRAN, www.armitran.eu).

The results guided the scaling up process in order to investigate effects on a European level (EU-27).

This was a complex procedure and because in many occasions no significant differences were found for the simulation models to be applied, then a more indirect, simplified process was adopted. This is a linear extrapolation of findings — for those findings that European geographical scaling up is possible. Scaling up is plausible for journey duration and percentage of time spent with very small headways based on relevant statistics that are readily available for EU. The latter scaling up effort is based on DFOT results and scaling up is based on statistical significant findings. Nevertheless, scaling up for headway results is presented with reservation.

The generic scaling up process was based on both a quantifiable and an inferential approach depending on the availability of data on EU level, indicators, and results:

Firstly, scaling up was set to be carried out with consideration of reported European statistics (i.e. EUROSTAT, statistical pocketbook 2012) and not relevant studies. Replicability is a process that leads to effective scaling up because of cumulative generalisability power. Similar studies are not abundant but do exist, however, they share more differences than similarities and to use these studies for scaling up would involve even further hypothetical assumptions to be made. Their role would be more useful for validating first the aspects or
results that should be scaled up. The association of efficiency findings to European statistics is less fuzzy and more straightforward.

Secondly, scaling up was carried out per function bundle tested within TeleFOT. In case where significant findings were available for separate functions, they are presented; this was possible either because they were tested separately (e.g. in Greek LFOTs/DFOTs) or comparison between baseline treatment resulted in the effect coming from one added function. It was difficult—and sometimes impossible—to isolate the effect of single functions as they were used as a bundle. If comparable bundles existed (e.g. baseline with treatment), then it was carried out.

Thirdly, confidence intervals (CIs) should be included for estimations presented, as they are safer alternatives than strict numbers but as some of the general results used for scaling up are aggregated, then to aggregate their CIs would not make sense. It was more appropriate to include range of number with consideration of the difference in Standard Deviations (SDs) between groups of statistical significant result as it provides a simple effect size. Differences in standard deviation have higher transferability value as they can be standardised and still be meaningful.

Fourthly, estimations are provided for three penetration rates in the European transport system (20%, 50%, and 100%).

Finally, the restrictions for scaling up are considered throughout this process. The findings are scaled up for passenger cars only and they do represent the greatest percentage in European transport activities (73.7% within Europe in 2010, EUROSTAT Pocket Handbook, 2012) but not all of them. Their interactions with other road users or specific scenarios are not included. Data weights (e.g. certain road types, certain types of journeys) were not calculated for these indicators that significant findings did not exist even if stratification in analysis was carried out and tested and, also, for those indicators that weighting was not feasible or not relevant.

The differences in types of nomadic devices used and geographical topology characteristics make it harder to scale up findings on a European level. In most occasions, differences were not significant within FOTs or similarity in differences was not found for different FOTs (regardless of significance). Efficiency is extremely difficult to scale up without extrapolations based on simulations. Generalisability for some cases is limited as findings are based on DFOTs.
These findings present limitations for scaling up to European level as the fundamental research findings respond to answering questions for data not yet available. For example, it is feasible to estimate the km driven per road type in Europe but it is difficult to estimate journey duration for different types of journey (e.g. commuting, leisure).

Therefore a set of guidelines, some more arbitrary than others, have been developed to encompass the essence of main findings and inferences. It has been repeated many times within this deliverable that certain assumptions were adopted in order to answer the respective research questions.

Certain assumptions do apply also when attempting to generalise these findings to European state members. Two core assumptions were implemented:

- If European statistics are not available then scaling up will be based on TeleFOT research (the inferential arbitrary approach);
- Estimations for three different penetration rates yielded statistics on linear, quantifiable terms (i.e. if one third of passenger cars in Europe are equipped with this function, then the decrease or increase will be one third of significant result).
  - For example, If half passenger cars are equipped, then half decrease in journey time is expected (very simple linear relationship assumed for scaling up to be drawn but constraints and limitations are discussed within this deliverable in the relevant sections)

As no related statistical data exist, then the extrapolation to European level was applied only for significant findings (as generalisability is statistically accepted for significant findings). In addition, the extrapolation basis is actually FOTs themselves. Limitations are apparent but this information is helpful and useful for diverse types of stakeholders (ranging from policy makers, regulators, and infrastructure designers and operators) involved in traffic management on many levels of engagement (i.e. macro-, micro-, and direct and indirect).

It has been found that in Europe 274 hours per person a year are driven (Commerzbank, Roland Berger Report, 2001). Extrapolation based on this suffers from two limitations. The approximation is for all travelling in EU regardless of journey types. The extrapolation is from specific journey OD pairs to all travel duration. As EUROSTAT does not provide such statistics, then findings are based
on either other sources or country specific ones. The source might not hold the inferential power required for scaling up but it is the available source so far.

Therefore, the following picture presents the scaling up of journey duration significant findings (i.e. 10% decrease in journey duration because of system with navigation, green driving and traffic information).

---

**Figure 45. The possibilities for 100% scaling up the decrease in journey duration because of bundle of functions (navigation support and traffic information)**

If 473 passenger cars are counted per 1000 people in Europe, then 234,135, 000 passenger cars are counted for all Europeans. In this calculation, the whole population of Europe is considered (although, of course, not all of them are drivers; children, elderly, etc.). But also for the EUROSTAT calculation (i.e. per 1000 people) the whole population is regarded. Presuming that the functions might have different penetration rates for all passenger cars in Europe, full penetration will probably not be attained. Penetration rates at 20% and 50% are more probable as devices are already in market. Statistics used are statistics that are available, such as passenger transport (4738 billion pkm in Europe for 2010 compared to 5828.4 in USA for 2009, percentage of passenger cars accounted for (73.7%) based both on time travelling per person in Europe and adjusted penetration rate. This adopted penetration rate is minimum likelihood and not actual.
Significant change was found in LFOT2 (Sweden) for 87 participants with
decrease in 10% (mean: 1.7 minutes) in journey duration for common journeys.
Decrease was found for common OD pairs and assumption is made that this
decrease could be the same for other journeys.

With **20% penetration rate**, 20% of passenger cars will be equipped with this
bundle of functions (then 95 passenger cars per 1000 people in Europe). If saving
in journey duration is 10% because of the system used, then saving is still 26.93
hours for each driver per year. The saving in time for 20% of passenger cars in
Europe (13,330,350) would be **359 million (range: 253 m-465 m) hours per
year for EU-27.**

With **50% penetration rate**, 50% of passenger cars will be equipped with this
bundle of functions (then 237 passenger cars per 1000 people in Europe).
Decrease in journey duration for 50% of passenger cars in Europe (117,315,000)
would be, in total, **3.2 billion (range: 2.23 b– 4.1 b) hours per year for EU-
27.**

For **full penetration (100%)** and 10% decrease in journey duration for all
journeys made by each driver in Europe, saving of 27 (range: 21.5-34.8 hours)
hours (1615.5 minutes; range: 1292.4-2090.6 minutes) would be possible
because of using this bundle of functions. Taking into consideration available
passenger cars, then potential saving in travel times for all passenger cars within
Europe might be **6.3 billion (range: 5 b-8.2 b) hours per year for EU-27.**

Decrease in journey duration would potentially affect traffic flow in heavier traffic.
The positive impact to efficiency via effect of journey duration to traffic flow is not
clear and evident. For example, by using navigation support drivers would choose
other alternative routes and avoid congested areas as they are informed about
traffic. Flow should be affected mainly because of its more harmonious re-
distribution.

Headway values (both distance and time) are not available on a pan European
level. This scaling up is for: **navigation support with ADAS, navigation
support with traffic information and ADAS, navigation support with
traffic information/speed alert and ADAS.** The two second “rule of thumb”
could be used for car following behaviour as safe distance keeping behaviour and
pkm driven across Europe. Decrease in time spent with dangerously small
headways will be extrapolated based on number of passenger cars per 1000
people in Europe (for penetration rate calculations) and passenger kms within EU.
As the effect is not additive, ADAS effect was not considered to be linear and it was not removed. Effects were not assumed to be a result of a simple subtraction.

In average, by using navigation support, speed limit information or speed alert with ADAS, drivers spent 5.87% less time with dangerously low headways (66.7% less time compared to pure baseline condition). Three penetration rates were calculated.

For penetration rate 20%, each driver spends 66.7% less time (8.8% baseline – average 2.93% with functions and ADAS) with very dangerous small headways and each driver spends 274 hours per year in the car. It is important to make it clear that approximately 67% is the reduction in driving time with dangerously small headways and not the actual time they spent driving very close to any preceding vehicles in the network. Therefore, a driver with no function on will drive 24 hours per year with dangerous headway values and a driver with any function on with ADAS will spent 8 hours with very small headway values (difference 16.1 hours). If this is the gain for one driver per year, then the next step is to find the gain in time spent for the whole Europe. For 95 passenger cars in 1000 people, the gain would be 1528 hours less per 1000 people in Europe.

Likewise, for penetration rate 50%, gain per 1000 people in Europe would be 3802.92 hours less with dangerously small headways.

Likewise, for penetration rate 100%, gain per 1000 people in Europe would be 7605.84 hours less with dangerously small headways.

However, it should be taken into consideration, though, that this extrapolation holds true mostly for driving spent in heavier traffic or congestion for small headways to exist. As most time is spent in free flowing traffic for most driving taking place in Europe, then this extrapolation should be adjusted specifically for driving in heavier traffic and/or congestions depending on what type of statistics are available.

Specifically, for traffic congestion, it has been found (ERC, 1999) that German citizens spent 11 hours in traffic congestion per year (for calculations average speeds given for congestion were included). Therefore, 4% of driving time per year was spent in congestion in Germany. These numbers are conservative as the
available statistics are over a decade old and the congestion problems have increased since then.

Applying these numbers for the whole of Europe, then for 20% penetration rates and only for time driven in congestions, 61 hours less for 1000 people in Europe will be spent will dangerous headway values in traffic congestion.

Likewise, for penetration rate 50%, gain per 1000 people in Europe would be 152 hours less with dangerously small headways in traffic congestion.

Likewise, for penetration rate 100%, gain per 1000 people in Europe would be 304 hours less with dangerously small headways in traffic congestion.

Decrease in hours spent with dangerously small headways affects both safety and efficiency. Efficiency is indirectly affected. If drivers spent less time with dangerous headways, then there are fewer possibilities for an accident to occur because of close car following (unfortunately relevant statistics do not exist). If an accident is less probable to happen, then there are fewer threats for traffic and, specifically, for string flow (destabilisation factors). Stability in string flow (because of car following) is related to intervehicular spacing (Darbha & Rajagopal, 1999). Min headway values differences were found to be greater when functions were used in comparison to when they were not used but the differences were not of significance and of no value for the scaling up process. Ranges were not estimated for time spent with very small headways as they are not beneficial for these calculations.

Subjective assessment of avoided traffic jams and delays rely heavily on participants’ feelings for scaling up to be of any value. In addition, statistically significant differences were not revealed, if they were revealed scaling up would have been based on comparisons of TeleFOT questionnaire data to other user uptake surveys conducted within Europe. The majority of users in most LFOTs (with the exception of Greek F LFOT3) reported they perceived/felt no change in avoiding traffic jams and delays because of using the traffic information function. Moreover, road characteristics and urban environments, and regulations are important for defining the success in avoided traffic jams and delays because of these specific functions. Change in speed variations because of these functions were not attained and therefore these findings were not extrapolating on European level.
Further stratifications for road types were not carried out for scaling up because with the already included assumptions, the extrapolations would rather be unsubstantiated. If certain numbers and estimations existed for EU-27, then inferences would be more feasible to be made for scaling up these results.

It is difficult to predict the numbers for the next five years due to the current economical situation in Europe. For example, according to European statistics, a decrease of 1.2% in registration of new vehicles was recorded between 2009 and 2010. The effect of increasing unemployment figures, decrease in registration of new vehicles, and increase in fuel prices would probably decrease any gains from scaling up of findings on journey duration and headway distribution indicators estimated above. In addition, it is not clear if the impact from such factors, such as socio-economic factors, will be counterbalanced by exponential growth in technology innovations and sales of nomadic devices.

However, the findings and databases from TeleFOT project could be the basis for creating European data in collaboration with other related projects (e.g. EuroFOT) for both ADAS and bundles of functions. Such an endeavour requires both creating methodologies for harmonising the data and also close collaboration with the European statistical agency for assessing the harmonising process in order to follow an acceptable procedure according to standards set for data they process.

Finally, scaling up results should be considered within the framework of Horizon 2020 and what these outcomes have to offer to future European transport research.
6. CONCLUSION

The focus of this deliverable was to present the main findings for each research question investigated within the efficiency impact assessment area.

Increasing traffic efficiency is a goal aimed at harmonised traffic flow, optimal traffic volume, increased road capacity, fewer accidents, and greater accessibility for all involved road users. Consideration in TeleFOT is made solely for passenger cars and not other involved road users that are affecting traffic elements (e.g. modal choice or change). Efficiency is considered from the driver’s perspective. Three elements of traffic efficiency were considered within the TeleFOT model: traffic flow, traffic volume, and accessibility. Certain indicators were determined and measured within the TeleFOT methodology framework specifically for the efficiency impact assessment area. Main findings per investigated efficiency research question are presented in respective sections.

Not all functions affect traffic efficiency and not all functions play the same role (either primary, secondary, or neutral) in different impact areas.

As anticipated, navigation and traffic information seem to be the most important functions for efficiency. Speed limit information and speed alert have a secondary role. The effect of green driving support is not clear; it seems conflicting. It appears that GDS increases travel duration (negative effect) but decreases variation –as much as almost the rest of functions-in headways. The effect of functions and ADAS appears to be complementary and not conflicting wherever it was possible to investigate separate impacts. The combined effect of ADAS and TeleFOT functions is more complicated than to be expressed as additive.

It is important to mention that a set of sustainable structural indicators could be set for monitoring the effect of functions to traffic and driver efficiency that could infiltrate the development of next generation of assistive and information systems and would prove useful for strategies within policy making for nomadic device deployment. These indicators, as discussed in previous sections, would be time duration (e.g. journey) and headways as they are both easily and universally measurable. Objective assessment for delays and avoidance of traffic jams should be based on more complex algorithms than certain sets of assumptions and restrictions. Subjective evaluation is actually correlated to exposure but these would hold true also for objective assessment for different pilot sites.
TeleFOT was a huge effort with clear execution steps from initial hypothesis building up to analysis. The main factor distinguishing TeleFOT from other FOT projects is the innovative methodological framework of FOTology with clear distinction from the generic exploratory naturalistic methodology. It was a co-ordinated effort borrowing fundamental aspects from “traditional” experimental testing (i.e. research questions, hypothesis testing, additional DFOT data analysis, diverse data sources in one unified and accessible database).

The TeleFOT data could provide baseline datasets for the new functions to be tested in the future.

For the innovations to come, in both methodologies and technologies within Horizon 2020, the goal stays the same. Drivers must be protected from hazardous traffic conflicts, even when the surrounding traffic cannot be controlled, they should be educated and trained about their behaviour behind the wheel, and key messages should be effectively translated for the different stakeholder groups. Lessons learnt from FOTs conducted in Europe and the barriers that researchers had to overcome are important steps towards standardising FOT methodologies.

Public authorities and road operators recognise that these functions offer diverse possibilities to alleviate problems on EU roads. Researchers identify impacts of these functions on different driving areas. Last but not least, car industries and suppliers consider the systems an important product innovation and a competitive advantage. The potential of enhancing these functions in the near future and integrating them in cooperative systems will soon change the research and industrial scenery.
7. REFERENCES


ANNEX I – TESTED DEVICES

This annex gives a short description of devices tested at each FOT. More information can be found from TeleFOT deliverables D3.3.2, D3.5.1, and D3.6.1.

Finnish LFOT

In the Finnish LFOT the nomadic device, on which the user interface of the applications was implemented, was the user’s own mobile phone. The applications support Nokia Symbian phones (N and E series phones, as well as Nokia 6210 Navigator).

Traffic information, and speed information and alert were provided by LATIS™ which was a location aware traffic information solution for drivers. LATIS™ utilized a built-in speech synthesizer to read aloud announcements of nearby incidents or other relevant information related to major road work, congestion, unexpected changes in road weather conditions, etc. Online map service was used to display the user’s position and the exact location of the incident. Current speed and speed limit information were also displayed. The current speed was read aloud, if it exceeded the speed limit. Manual "one button" reporting of traffic incidents enabled users to provide traffic information.

The LATIS service was integrated with DRIVECO service provided by a Finnish company EC-Tools. DRIVECO personal was a green driving advisor for smartphones and an automatic driving diary. DRIVECO collected information on fuel consumption from a separate module connected to OBD-II vehicle interface. The module sent data over Bluetooth to a smartphone running DRIVECO software. Journey summaries were further collected from the smartphone to a web service for reporting and feedback. GPS logs could be used for generating a diary.

Greek FOTs

LFOTs

In Greek LFOT 1, the Sygic navigation software was used. It presented to the driver the navigation interface, namely route selection screen plus route guidance screen and vocal output. In LFOT2, the navigation software presented together with the navigation support the speed limit information to the driver, through a visual speed limit traffic sign on the screen of the nomadic device. In LFOT3, the navigation software presented together with the navigation support the traffic information to the driver, through visual icons and text on the screen of...
the nomadic device. Some acoustic tones were also used. In LFOT 4, the navigation software provided together with the navigation support a warning to the driver, when he/she is driving with a speed greater than the speed limit in the current road segment. The warning was visual on the screen of the nomadic device and acoustic. The software ran on the Samsung OMNIA II nomadic device.

**DFOTs**

In Greek DFOTs the same nomadic device and integrated functions were used with the LFOTs except traffic information. In addition, in Greek DFOTs (1-3) tests were carried out with an instrumented vehicle and Lane Departure (haptic and auditory) and Forward Collision (auditory) Warnings were given to the driver.

**Italian LFOT**

The Nomadic device implementing the functions tested in the LFOT in the Italian test was a smartphone which was commonly available in the Italian electronic consumer market in 2010: ACER E101 BeTouch. Microsoft Windows Mobile v5.5 was the Operating System. Users could interact with the smartphone through a touch screen.

Static navigation and speed alert / speed limit information were accessible through a software application developed by BLOM. The application, called Two Nav v2.2.1a – TeleFOT release, allowed drivers to use the navigation system and to experience the speed information service.

**Spanish LFOT1**

The nomadic device that used in the Spanish LFOT1 was a navigation device from NDrive. This device was a personal navigation solution based on GPS technology. It provides navigation through visual and voice instructions, which included names of roads and locations, door-to-door navigation and detailed information about points of interest in several languages.

**Swedish LFOT2**

The device used in the Swedish LFOT2 was the Garmin Navigator in the Nüvi series with EcoRoute. EcoRoute is a new part of Garmin’s navigation software that gives indications on how “green” you drive based on GPS data (speed relative speed limits and rate of acceleration). EcoRoute also gives routing advice according to lowest fuel consumption and gives the user a possibility to compete in green driving.
UK LFOT

The UK LFOT studied the impact of use of the BLOM N-Drive PND. It provided navigation support (static), speed limit information and speed alert.

German DFOT

The device which has been used in the German DFOT is NDrive TouchXL SE with customised software, named TwoNav Easy, from BLOM. The customised software enables the possibility to log beside the position and velocity, also user inputs, i.e. button presses of the driver. The German DFOT uses several functions which are divided into functions of the nomadic device and advanced driver assistance systems (LKA, ACC, and FCW\(^{14}\)) which are implemented in the vehicle. The nomadic device provides three functions to the driver: static navigation, speed limit information and speed alert. Static navigation is a common application which guides the driver with visual and acoustical advises to his desired destination. The pre-installed map on the nomadic device contains speed limits on the roads. The current speed limit is displayed as a traffic sign in the lower left corner of the nomadic device with the result that the driver is always informed about the current speed limit on the road he is driving at. The nomadic device always compares the velocity over ground with the current speed limit on the road and in case of speeding of the driver, the traffic sign displayed on the screen turns red to inform the driver of his misdemeanour.

UK DFOT2

The UKDFOT2 utilised the Foot-LITE system which is a ‘Smart’ driving system which incorporates Green Driving Support (GDS) with safety features of Lane Departure Warning (LDW) and Forward Collision Warning (FCW). Foot-LITE provides the driver with feedback and information on Smart driving behaviours in the vehicle, in real time via an integrated visual interface presented on a Smartphone (HTC HD2). The Smart driving advice offered is based on numerous internal parameters, with data being collected via an adapted lane departure warning camera and OBD-II port, as well as accelerometer and GPS.

\(^{14}\) LKA: Lane Keep Assistance  
ACC: Adaptive Cruise Control  
FCW: Forward Collision Warning
ANNEX II – STATEMENT OF PRINCIPLES REGARDING DATA-SHARING FOLLOWING TELEFOT

The aim of the TeleFOT project is to disseminate the results of the project to a wide audience outside of the TeleFOT partnership. This includes the European Commission, TeleFOT associate partners (e.g. national organisations that have directly or indirectly supported the TeleFOT data collection), stakeholders of the road transport system and the scientific community. Such an audience may need the TeleFOT results for understanding the wide-scale implications of the uptake of aftermarket and nomadic systems, particularly with regard to Safety, Mobility, Efficiency, Environment and User Uptake.

The Large-scale FOT (LFOT) data has been collected and incorporated into a set of electronic systems which are held centrally and which have been accessed by the partners for analysis purposes. Due to the complexity of these data and the statistical requirements for their analysis it is envisaged that future access after the project duration will be through the IP co-ordinator.

The Detailed FOT (DFOT) data is held and has been analysed mainly at a local level although data has been made available to other partners for analysis during the project lifetime (to address specific research questions) on request.

Overall, the working principle remains that the data are fundamentally a European resource and that they should be used and exploited as widely as possible both within and external to the partnership. However, data distribution is to be handled according to a specific protocol. The following principles are therefore proposed:

- Third-parties (for example national organisations) who have supported the collection of the data within the TeleFOT project will be given access to the aggregated LFOT data on written request.
- Third-parties who are not affiliated to the TeleFOT will not be given automatic access-rights to TeleFOT data but may apply for specific analyses to be conducted on their behalf. If analyses are required once the project has been completed, an application should be made to the TeleFOT Project Co-ordinator in the first instance who will pass the request on to an appropriate partner (for example, Impact Assessment WP Leaders).
- A charge may be made for analyses of the data if requests are made once the project has been completed.
- The European Commission may wish to sub-contract further analyses of the combined data to one or more of the partners (for example Impact Assessment WP Leaders) to support future policy and decision-making. The financial support for this work will be agreed outside the arrangements for TELEFOT.

Therefore, each full TeleFOT partner will be able to access and use the combined database for other research activities after TeleFOT has been completed.

Some general principles regarding data from the TeleFOT subjects are also necessary and these are proposed to be as follows;
Security

- Data will preferably be stored locally on password protected servers and PCs.
  Once paper versions of questionnaires have been computerized, the paper versions will be shredded at the end of the project.
- Data on servers will be regularly backed.
- Access will be made available (i) to project partner staff responsible for data analysis and, (i) after the project, to researchers granted permission by the European Commission

Consent

- Written & signed consent has been obtained from all participants for collection and processing of data
- Copies of consent forms will be kept for a minimum of 10 years.

Publication

- Published results will be anonymized
- No information will be published that would allow individuals to be identified
- If the results contain any personal data (see below), the specific consent of the data subject will, wherever possible, be obtained.

Personal data: Data relating to a living individual who can be identified from that information or from that data and other information in possession of the data controller. Includes subject name, address, telephone number and id number. Also includes expression of opinion about the individual, and of the intentions of the data controller in respect of that individual.