Impacts on safety - preliminary results from available data: TeleFOT [Field Operational Tests of Aftermarket and Nomadic Devices in Vehicles] D4.3.2

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### Impacts on safety – Preliminary results from available data

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<tr>
<td>DFOT</td>
<td>Detailed Field Operational Trial</td>
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EXECUTIVE SUMMARY

This deliverable presents some **interim results** using TeleFOT FOT data that were **available up to March 2012**. The aim of the deliverable is to present initial results from the FOTs which establish that the data being collected are sufficient for answering the research questions related to safety in terms of dependent, independent and explanatory variables and to determine in greater detail the nature of the final analyses that will be undertaken. Each safety research question is considered in turn.

In general it is shown that the data will be sufficient to answer the research questions. There are still requirements for some RQs that ideally need map-matching data but this type of data has only recently become available and it was not possible to use this data in this initial analysis activity. Furthermore, some RQs require data from Detailed FOTs (DFOTs) before they can be addressed. At the time of the preparation of this Deliverable, many DFOTs were on-going and therefore analysis work on tackling the research questions which are dependent upon them has not yet started.

The Deliverable has considered all 7 Safety Research Questions. Experience with the interim analysis of the available data has shown that in some cases, it has been possible to make significant progress with respect to addressing the research questions (such as SRQ-2, SRQ-3) whilst as expected, in other cases only limited progress has been possible due to availability of the data.

For a summary of the main findings for each safety research question, reference should be made to TeleFOT Deliverable 4.2.3 where summary tables for each RQ in each Impact Assessment domain can also be found.

Overall, there is confidence that the TeleFOT data will be sufficient to provide meaningful results and that it will be possible to interpret the results in the context of a number of background factors when the remaining data are available.
INTRODUCTION

TeleFOT is 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 1 June 2008, TeleFOT aims 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 assesses via Field Operational Tests (FOTs) 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 aim at a comprehensive assessment of the efficiency, quality, robustness and user friendliness of in-vehicle systems, such as ICT, for smarter, safer and cleaner driving.

This deliverable reports on the progress made in WP4.3, Safety Impact Assessment since the development of the initial analysis plan D4.3.1. For each research question in the safety impact assessment further development of the analysis approach has been undertaken and in most cases an interim analysis of available data has been carried out for associated hypotheses. The approach taken for each RQ and the results based upon data available the TeleFOT database is presented in the subsequent sections of the report. General approaches for statistical testing are discussed in a later chapter.

Wherever possible tests for statistical significance for each analysis have been performed, however, due to the time frame of the data flow within the project there are insufficient data to answer all of the hypotheses robustly. It should however also be noted that the importance and relevance of carrying out a complete and rigorous analysis is not to be underestimated and is considered critical for the successful completion of final analyses. These will be reported in due course, firstly in the updated D4.2.4 in month 54 and then in the final analysis report for WP4.3.

This deliverable is of direct relevance to D4.1.3 (Trial analysis report) and D4.2.3 (Overview of results from WP4.3 – WP4.7) and a summary of the detail presented here will also form part of these deliverables.
CONCEPT OF SAFETY

Typically safety is monitored through the number of accidents occurring and the severity of the accidents. Improvements in safety warrant both a reduction in the number of accidents and, in the event an accident does occur then a reduction in the severity of the injury outcome for those involved. The converse holds when considering dis-benefits for safety.

A number of factors are known to contribute to the likelihood of an accident occurring and to the extent of the injuries expected. These are associated with driver characteristics, driver behaviour and the road environment along with measures of exposure on the road as a driver.

Different types of roads can pose more of a risk of accidents occurring than others. Road Safety Foundation (2009) takes account of 45,000km of the country’s motorways and A-roads and found that 62% of fatal or serious collisions happen on single carriageways, 13% on dual carriageways and 10% on motorways. They also found single carriageways are twice the risk of dual carriageways and 6 times riskier than motorways. Risk is 30 percent higher on non-primary A roads compared to primary A roads. Chipman, MacGregor et al. (1993) showed among other factors such as time of day and road choice the amount of exposure (distance travelled and time it took) has an effect on the drivers crash risk. They also conclude that time spent driving may be a better estimate of risk than distance as people take more time to drive through more hazardous situations so can give an estimate of the high and low risk road segments. Janke (1991) states that ‘if two groups of drivers are equally competent and prudent, but differ in miles driven, the higher mileage group will have more accidents on average because of their greater exposure to risk’.

The Department for Transport (2009) shows that on all types of road and in all weather conditions there were 124,541 accidents in daylight and 170,591 accidents in the dark. Lin, Fearn (2003) found that night time driving restrictions effectively reduced the likelihood of a fatal injury in young drivers. Ranney, Simmons et al. (1999) found using a simulator study that it takes longer to detect targets and also found impaired critical tracking performance during night time conditions. Anderson, Holliday (1995) also found effects of the dark on driver’s performance in relation to contrast sensitivity. Simulated
lens opacities that have no effect on day time measures of visual acuity had a significant effect on night time measures of contrast sensitivity for moving targets, meaning anyone with impaired vision could perform significantly worse when driving at night compared to in the day. The weather can also have an effect on driving performance. Keay, Simmonds (2006) found that rainfall consistently represents a driving hazard. Similarly Brodsky, Hakkert (1988) found that added risk of an injury accident can be two to three times greater in the wet than in the dry. A more recent study by Brijs, Karlis et al. (2008) found similar results.

Driver fatigue is known to occur when driving requires sustained attention over long periods (Lal, Craig 2001). Häkkänen, Summala (2001) found driver fatigue, when taking into consideration those who had fallen asleep and those who had felt tired preceding the accident, was estimated to occur in 4% of trailer truck drivers involved in accidents. Connor, Norton et al. (2002) found decreased levels of self-reported alertness were associated with increased risk while driving. There was also an eightfold increased risk if drivers reported sleepiness. Lardelli-Claret, Luna-Del-Castillo et al. (2003) found that drowsiness was strongly associated with collisions, surprisingly even more so than for alcohol usage. Ting, Hwang et al. (2008) found that in the last 10 minutes of a 90 minute simulated driving task median reaction times were 0.31 seconds longer than in the first period of the session, this equates to an additional 8 meters in stopping distance if the driver was travelling at 100km/h. The results clearly demonstrate that the effect of time-on-task is a significant cause of fatigue and risk of accidents.

The secondary task of interacting with the in vehicle information system (IVIS) may have an effect on the drivers workload which could lead to reduced safety if carrying out the primary task of driving and the secondary task of interacting with the IVIS exceeds the drivers threshold. Törnros, Bolling (2005) looked at the effects of mobile phone use on driver workload and the effects this had on performance. They found that both hand held and hands free phone use while dialling had an effect on the lateral control of the vehicle and this was ‘interpreted as an indication of reduced safety’. Santos, Merat et al. (2005) found that when comparing driving with and without an IVIS system in use, in both a simulated environment and on the road, participants self-report data indicated that they clearly felt a performance decrement in the simulator and instrumented vehicle when IVIS was in use. Hamish Jamson, Merat (2005) looked at IVIS systems and both the
visual and cognitive demands these can place on the driver. They found that drivers ‘seemed incapable of fully prioritising the primary driving task over either the visual or cognitive secondary tasks as an increase in IVIS demand was associated with a reduction in driving performance: drivers showed reduced anticipation of braking requirements and shorter time-to-collision’. This shows how IVIS systems could possibly have an effect on driver safety if they lead to increased workload and so change their behaviour such as leaving less braking time. Hancock, Verwey (1997) also suggests that high workload tasks may lead to fatigue which is also believed to affect safety, see ‘is fatigue affected’ section above. Blanco, Biever et al. (2006) looked at the effect of IVIS systems on driving performance and found that multiple decision making elements in a task had a negative impact on driving performance of both car drivers and truck drivers when compared to tasks with only one decision-making element. They also said in reference to cognitive demands that ‘this single factor may influence the safety of the automotive tasks to a greater degree than any other factor’.

A nomadic device could possibly affect the visual behaviour of the driver which could intern lead to an increased likelihood of collisions. Information collected from police reported crashes found that up to 12.9% of crashes were identified as being due to the driver being distracted. Of the 12.9% up to 64% of these distracters could be classed as being in vehicle visual distractions e.g. adjusting radio, adjusting climate control or dialling a mobile phone (Stutts, Reinfurt et al. 2001). Horberry, Anderson et al. (2006) found that in vehicle tasks such as interacting with the entertainment system can affect driving performance, such as the driver’s ability to maintain speed and their preparedness to react to unexpected events. Reed-Jones, Trick et al. (2008) found that devices with a higher static time on task (time spent interacting with the device) produced significantly more lane deviations than devices which required less interaction. They also found some in vehicle distracters had significant impacts on collision and hazard response time. Maciej, Vollrath (2009) found a strong distraction effect caused by in vehicle information systems with reduced lane discipline and increased reaction time needed to change lane. This was shown to be mainly due to visual distraction shown by the 30 to 40% off windscreen glance time. Memarovic (2009) showed similar results, finding that drivers using a navigation device with a graphical display spent less time looking at the road in comparison to a device that gave audible directions only. Memarovic also found a correlation between glancing at the display and a higher variance
in driving performance measures. In a recent simulator study by Chisholm, Caird et al. (2008) it was found that when drivers interacted with an iPod there was an increase in collisions and perception response time. They also found that difficult iPod tasks significantly increased the amount of attention directed in the vehicle. Chisholm, Caird et al. (2008) conclude that ‘future research should identify related device functions (e.g., on other MP3 players, Blackberries, iPhones and so forth) that produce prolonged glance behaviour’.

Aarts, van Schagen (2006) conducted a review of the link between driving speeds and the risk of road crashes. They said ‘at high speeds the time to react to changes in the environment is shorter, the stopping distance is larger, and manoeuvrability is reduced’. Maycock et al (1998) (as cited in Aarts, van Schagen (2006)) found that a 1% increase in speed is related to a 13.1% increase in crash liability. Kloeden, McLean et al. (1997) found cars involved in casualty crashes were generally travelling faster than cars that were not involved in a crash and more importantly 14 per cent of casualty crash involved cars were travelling faster than 80 km/h in a 60 km/h speed zone, compared to less than 1 per cent of those not involved in a crash.

Patel, Council et al. (2007) found approximately 40% of all 2004 fatal crashes were single-vehicle, run-off-the-road crashes, and also noted ‘the problem was even more significant on two-lane rural roads, where shoulder rumble strips were an important treatment in the prevention of these’. This shows how important maintaining appropriate lane positioning is, as deviations in lateral control accounts for a high percentage of automotive fatalities. Knipling (1993) found ‘the most common contributing causal factor associated with rear-end crashes is driver inattention to the driving task. A second, and overlapping, major causal factor is following too closely. One or both of these factors are present in approximately 90 percent of rear-end crashes’. Therefore device affects proximity to the vehicle ahead then this can have a major effect on the vehicle occupant’s safety.

Lamble, Kauranen et al. (1999) found drivers detection ability in a closing headway situation was impaired by about 0.5 s in terms of brake reaction time and almost 1s in terms of time to collision, when they were doing a non-visual cognitive task whilst driving. Al-Darrab, Khan et al. (2009) found similar results, they discovered mobile phone call duration had more of an effect on the driver’s braking response times than
both time of day or headway between the cars. These studies show how driver
distraction can have an effect on braking behaviour which could possibly have an effect
on the driver’s safety as well as the safety of any other road users who are in close
proximity.

Based upon this knowledge, together with an assessment of the feasibility of collecting
data to support analysis, a number of safety research questions and hypotheses were
developed (reported in D4.3.1) in relation to the use of nomadic information systems in
passenger cars. These were;

**SRQ1  Is the route affected (where travel takes place)?**

- **H1.1** There is a change in the proportion of road types driven on when the device
  is used compared to when it is not.

- **H1.2** People choose different routes (based on road type) when the device is used
  compared to when it is not.

- **H1.3** There is a change in the proportion of urban/rural driving when the device is
  used compared to when it is not.

**SRQ2  Is the amount of time on the road affected (how long travel takes place for)?**

- **H2.1** Subjects report a change in the number of trips undertaken because they
  have the device.

- **H2.2** There is a change in the distance travelled between comparable origins and
  destinations.

- **H2.3** Subjects report a change in the distance travelled between comparable
  origins and destinations.

- **H2.4** There is a change in the duration of journeys travelled between comparable
  origins and destinations.

- **H2.5** Subjects reports a change in the duration of journeys travelled between
  comparable origins and destinations.

- **H2.6** There is a change in the length of time driven without a break.
SRQ3 Does the device cause distraction?

H3.1 The duration and/or frequency of glances to defined target areas of the visual scene changes

SRQ 4 Is speed affected?

H4.1 The number of speed violations / proportion of time spent in excess of the speed limit changes with the device

H4.2 There is a change in average speed

SRQ 5 Is vehicle positioning affected (proximity and lane positioning)?

H5.1 The longitudinal positioning of the vehicle will change as a result of having the nomadic device

H5.2 The lateral positioning of the vehicle will change as a result of having the nomadic device

SRQ 6 Is braking affected?

H6.1 The device changes braking behaviour

SRQ7 Is non-driving manual activity affected?

H7.1 There is a change in the duration of hands off wheel time

These form the basis of the safety impact assessment of aftermarket nomadic devices. In the following sections of this report, each research question is considered in turn. The level of detail included for each RQ varies due to accessibility of relevant data. Annex 1 provides tables indicating which tests sites are providing data (LFOT and DFOT) for the various safety RQs and which partner is taking the lead for the associated analyses.
In addition to the RQs noted above, the safety impact assessment will also draw upon relevant information provided by the other assessment domains within TeleFOT.
SRQ1 IS THE ROUTE AFFECTED (WHERE TRAVEL TAKES PLACE)

The hypotheses associated with this research question are as follows;

H1.1 There is a change in the proportion of road types driven on when the device is used compared to when it is not.

H1.2 People choose different routes (based on road type) when the device is used compared to when it is not.

H1.3 There is a change in the proportion of urban/rural driving when the device is used compared to when it is not.

The first and last hypothesis is related to actual logged behaviour, and the middle one to perceived reported behaviour.

The analysis that has been conducted to date in relation to these hypotheses is as follows;

Data analysed to date

Swedish LFOT2 and Spain, Valladolid LFOT data

These data have been analysed for Navigation, Green-driving, Traffic Information and Speed Alert?

The data analysed include Travel diaries, logged data and focus groups

Filtering/selection of data

Filtering out all but commuting trips, for logged data and only participants with more than 30 common trips were selected

- Most participants did not find that the device changed their route choice
Provisional Results

- The numbers are more or less the same for all functions – participants appeared to assess the device not the function
- A closer look at the data shows that the data corresponds well - i.e. the participants report that they drive slightly less on highways also say that they drive slightly more on rural roads. The total amount of driving is therefore constant.

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<td>Radical increase</td>
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Table 1 - Analysis for Traffic Information

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Table 2 - Analysis for Navigation

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Table 3 - Analysis for Green Driving

Statistical testing

The statistical analyses started with some simple checks in order to check for seasonal effects, a factor that can have big influence on driving behaviour as the seasonal variation in terms of weather is large in Sweden. Figure 1 shows a plot of weighted
average road type (i.e. highway/main/minor) use for all participants during the whole period and it quite clearly shows that the variation is low.

The analyses focussed on recurring trips in order to make comparisons between the baseline and treatment periods. In the data used (Swedish LFOT2), the number of recurring trips was very low, leading to a decision to increase the circle that defines a start or end point to a radius of 75m. This is still reasonable considering the possible precision of GPS logger on start-up and that car parks can be quite big and still should be considered as one point.

![Weighted road type means per day](image)

**Figure 1:** Weighted road type (i.e. highway/main/minor) means per day (the plot becomes scattered at the end because of the radical decrease in the number of logged trips as most participants stopped logging after 260 days).

Statistical analysis shows that at least for functions such as traffic information, the mean road type use is not a very good way to measure effects of the systems. Traffic information would not make a driver take a different route all the time, but instead might make a driver take an alternate route at those times that congestion is forecasted by the traffic information system on the normal route. Looking at the data confirms this; the proportions driven on the different road types in the baseline period and the treatment period are the same within 0.5%. Therefore, the initial analyses have been focused on
variance – the assumption being that Traffic Information will lead to higher variance and Navigation possibly will lead to lower variance.

The analyses so far indicates that over 90% of the variance can be explained by the variance in road type 0 (highways), which means that the analyses could be limited to analyzing the differences in variance of road type 0, which in turn means that a relatively simple f-test can be employed. The results show that there is a small trend toward increased variance, but no statistical significance could be proven.

Focus Groups

Focus groups with 20 participants of the Swedish LFOT2 confirmed the picture of the device as very useful at few occasions, making statistical analysis of effects on the total population very difficult.

“I think I used the device for Navigation three times during the test periods, but these times it was perfect, it could have led me right into the hotel lobby”

Next Steps with SRQ-1

The next step is to complete the analyses of all the other FOTs, to see if any of the devices had an effect on route choice, and if so try to explain why. It should also be possible to lift out those participants who in their questionnaires stated that they had changed their route choice and analyse those participants separately to see if the perceived change can be backed up with logged data. The analyses could then be focussed on finding the reasons why those people changed their behaviour, when others didn’t.
SRQ 2 IS THE AMOUNT OF TIME ON THE ROAD AFFECTED (HOW LONG TRAVEL TAKES PLACE FOR)

The hypotheses associated with this research question are as follows

H2.1 Subjects report a change in the number of trips undertaken because they have the device
H2.2 There is a change in the distance travelled between comparable origins and destinations
H2.3 Subjects report a change in the distance travelled between comparable origins and destinations
H2.4 There is a change in the duration of journeys travelled between comparable origins and destinations
H2.5 Subjects report a change in the duration of journeys travelled between comparable origins and destinations
H2.6 There is a change in the length of time driven without a break

SRQ-2, H2.1 Participants report a change in the number of journeys undertaken because they have the device

Data analysed to date;

• Questionnaire data
• Finnish LFOT and Swedish LFOT2 analysed
• Note that when full FOT data are available, the logged data will also be analysed and the results will be incorporated in D4.3.3

Statistical testing

• Friedman test, Wilcoxon test with Bonferroni adjustment
• Chi-squared test
Results to date - Green Driving Advisory System

These are as shown in figures 2 to 5. Overall, in Finland, the vast majority of participants reported that there was no change in the number of journeys that subjects undertook with the device. Some participants reported before the FOT that they thought the device would lead to a slight decrease in the numbers of car journeys but this was not the case after the FOT had finished.

![GD, impact on car journeys](image)

**Figure 2 – Impact of Green Driving Advice system on car journeys in Finland**

A similar situation was identified in Sweden (figure 3) although more participants reported before the FOT commenced that they expected the green-driving system to slightly reduce the numbers of journeys undertaken. By the time the FOT had been completed, this had reduced to practically zero.
The effect of the GD advisory system on public transport was also studied. In Finland, the vast majority of participants reported that they did not think that the Green-driving advisory system would make any change to the numbers of journeys they made by public transport (figure 4).

Figure 3 - Impact of Green Driving Advice system on car journeys in Sweden

Figure 4 - Impact of Green Driving Advice system on public transport journeys in Finland
However, in Sweden, some participants thought that the device would slightly increase the numbers of journeys they made by public transport although the numbers staing this diminished as the FOT progressed.

![GD, impact on PT journeys](image)

**Figure 5 - Impact of Green Driving Advice system on public transport journeys in Sweden**

**Results to date - Traffic Information System**

The effect of traffic information on journeys was also investigated (figures 6 and 9).
The data for Finland (figure 6) show that the vast majority of participants thought that a traffic information (TI) device would make no overall change to the numbers of journeys taken although a minority of participants reported that they thought the TI device would result in a slight decrease in the numbers of journeys.

The same results and same general trend was found for the Swedish FOT.

Figure 6 - Impact of Traffic Information system on car journeys in Finland

Figure 7 - Impact of Traffic Information system on car journeys in Sweden
The effect of Traffic Information was also studied for its perceived effect on journeys on public transport (figures 8 and 9). In Finland, whilst a small minority reported that they though the TI device would slightly increase the numbers of journeys they made by public transport, the over-whelming majority reported that they thought the device would make no change to the numbers of journeys and this was consistent throughout the FOT.

![TI, impact on PT journeys](chart.png)

**Figure 8 - Impact of Traffic Information system on public transport journeys in Finland**

In Sweden, the experiences were similar although a small number of participants reported that they thought that the TI device would slightly increase the number of journeys made by public transport whereas most participants finished the FOT by stating that it had made 'no change' to the numbers of journeys made by public transport.
Results to date – Speed Information (SI)/Speed Alert (SA)

Data for this analysis was only available for Finland although there was sufficient data to discriminate between car journeys and public transport journeys. For both modes of transport, the overwhelming majority reported that they thought that the SI/SA would make no change in the numbers of journeys taken (figure 10). A very small number of respondents commented that they thought the device would slightly decrease the numbers of journeys made but even these respondents had altered their response to ‘no change’ by the end of the FOT.
Figure 10 - Impact of speed information system on car journeys in Finland

For public transport journeys, the effect was even more marked (figure 11) with 100% responding that they thought that the device made no change to the numbers of journeys made. However, this result was completely in line with intuitive expectations.

Figure 11 - Impact of speed information system on public transport journeys in Finland
Results to date – Navigation

The final analysis for this research question relates to navigation. For this analysis, only results were available for Sweden (figure 12). Here, the impact on the number of car journeys was mostly ‘no-change’ - however, a small number of participants reported that they thought the device had slightly decreased the numbers of car journeys and as small number indicated that they thought it had slightly increased the numbers of journeys.

![Figure 12 - Impact of navigation system on car journeys in Sweden](image)

*Figure 12 - Impact of navigation system on car journeys in Sweden*

For public transport journeys, it was surprising to find that subjects reported that the device had made any difference (whether positive or negative) to the numbers of journeys they made. Whilst the numbers other than those reporting ‘no change’ were small, there were indications that the navigation system had radically decreased, slightly decreased, slightly increased or radically increased the numbers of journeys taken on public transport.
SRQ-2, H2.2 There is a change in the distance travelled between comparable origins and destinations

Data analysed to date;

- Travel diary data
- Spain-Valladolid and Swedish LFOT2 analysed

Filtering

- Only commuting journeys selected
- Sweden: No other exclusions
- Spain: Filtered out those who reported changes in their personal mobility needs
Statistical testing

- t-test
- No statistically significant change found in distance travelled between treatment period phases for any of the functions nor for journeys driven without activating any of the functions
- Comparison between baseline and treatment phase still needs to be done to complete the analyses

SRQ-3, H2.3 Participants report a change in the distance travelled between comparable origins and destinations

Data analysed to date;

- Questionnaire data
- Finland LFOT and Swedish LFOT2 analysed

Statistical testing

- Friedman test, Wilcoxon test with Bonferroni adjustment
- Chi-squared test

Results to date- Green Driving (GD) Advisory System

Data on a green driving advisory system were only available for Swedish LFOT2. Initially, the data indicates that over 50% of participants were expectant that a GD advisory system would slightly decrease the distance travelled (figure 14).
However, as the subjects became more experienced with the system and indeed at the end of the FOT, their opinions moved towards commenting that the GD advisory system would make ‘no change’ to distance travelled although a significant minority still felt that the device would ‘slightly decrease’ their distance travelled. There was also a small increase in subjects reporting that they thought the device would actually increase their distance travelled.

**Results to date - Traffic Information System**

Results on traffic information systems (TI) were available from the Swedish LFOT2 and Finland FOT. In Finland, a small number reported initially that they though the TI system would ‘slightly decrease’ their distance travelled but experienced changed their opinions towards ‘no change’ in distance travelled.
In Sweden, a similar effect was found but in this case, it was even more marked with over 40% initially reporting that they thought the TI system would ‘slightly decrease’ the distance travelled. By the end of the FOT, this had dropped substantially. Initially, some participants also reported that they thought the TI system would ‘slightly increase’ the distance travelled but opinions also altered to ‘no change’ with experience.
Results to date - Speed Information/Speed Alert System

Data on the effect of speed information/speed alert system on distance travelled were available from the Finnish FOT only. Here, the vast majority reported no change in distance travelled. Some participants reported a slight increase/decrease in distance travelled but the numbers were very small.
Figure 17 - Impact of speed information system on distance travelled in Finland

Results to date- Speed Information/Speed Alert System

Data on navigation systems were only available for Sweden. Here the participants had an expectation that the navigation system would slightly decrease the distance travelled (over 60% of participants) but by the end of the FOT, this had reduced to around 35%.

Figure 18 - Impact of navigation system on distance travelled in Sweden
SRQ-2, H2.4 There is a change in the duration of journeys travelled between comparable origins and destinations.

Data analysed to date;

- Travel Diary Data
- Spain Valladolid FOT and Swedish LFOT2 analysed

Statistical testing

- t-test applied to test differences between different phases of FOT on the duration of commuting journeys (treated as independent variables)

Filtering

- Only commuting journeys selected, average duration of commuting journeys calculated for each travel diary data collection period
- Sweden: No other exclusions
- Spain: Filtered out those who reported changes in their personal mobility needs

Results

- No statistically significant change found in duration of journey between treatment period phases for any of the functions nor for journeys driven without activating any of the functions
- Comparison between baseline and treatment phase still needs to be done to complete the analyses
SRQ-2, H2.5 Participants reports a change in the duration of journeys travelled between comparable origins and destinations

Data analysed to date;

- Questionnaire Data
- Swedish LFOT2 and Finland LFOT

Statistical testing

- Friedman test, Wilcoxon test with Bonferroni adjustment
- Chi-squared test

Filtering

- Only commuting journeys selected
- Sweden: No other exclusions
- Spain: Filtered out those who reported changes in their personal mobility needs

Statistical testing

- Friedman test, Wilcoxon test with Bonferroni adjustment
- Chi-squared test

Results to date- Green Driving (GD) System

Data were available from the Finland LFOT and Sweden LFOT2. For participants in Finland, a sizeable minority of participants thought that the GD system would slightly increase their duration of journeys between comparable origins and destinations. After experience with the system, most participants had reverted to reporting ‘no change’.
The results from Finland varied slightly with those from Sweden.

Figure 19 - Impact of green driving advisory system on journey duration in Finland

Figure 20 - Impact of green driving advisory system on journey duration in Sweden

At the outset of the Swedish FOT (figure 20), 50% of participants reported that their duration on roads of comparable origin and destination would slightly decrease through use of the GD advisory system. Also, 20% believed it would slightly increase their duration on roads of comparable origin and destination. Experience with the system...
resulted in most participants reporting no change but a minority were still of the opinion that the system slightly decreased the duration.

**Results to date – Traffic Information (TI) System**

Participants in the Sweden LFOT2 had relatively high expectations of this system with over 70% reporting at the FOT outset that they thought the TI system would slightly decrease their duration on routes of comparable origin and destination. By the end of the FOT, this figure had decreased but still over 30% of participants reported that the system had slightly decreased their durations.

![TI, impact on duration](chart.png)

**Figure 21 - Impact of traffic information system on journey duration in Sweden**

In Finland, the responses were slightly different. Whilst almost 30% reported initially that they thought the TI device would ‘slightly increase’ their duration, this changed over the course of the FOT such that by the end, hardly any participant was of the opinion that the device had increased their duration on roads of comparable origin and destination.
Results to date – Speed Information/Speed Alert System

Data on speed limit/speed alert systems were only available for Finland. At the start of the FOT, there was some expectation that the device would ‘slightly increase’ duration on roads of comparable origin and destination and this had not changed much by the end of the FOT. However, strangely, 100% reported that it made no change part of the way through the FOT.
Results to date – Navigation System

Data on Navigation systems were only available for Sweden.

![Graph: Impact of navigation information system on journey duration in Sweden](figure)

Participants expected that the system would affect their duration on roads of comparable origin and destination (by slightly decreasing the time spent on roads of comparable origin and destination). Whilst this fell away during the FOT, the results still indicated that participants were of the opinion that the system would be effective in this manner.

**SRQ-2, H2.6 There is a change in the length of time driven without a break**

The analysis of the hypothesis S-H2.6 “There is a change in the length of time driven without a break” was piloted with the logger data collected during 19 days of pre-phase of the Finnish LFOT and the pre-test travel diary filled by Finnish participants. Logger data included 3 946 journeys. All together 63 participants had reported 1 739 journeys to
the travel diary. Those included 1,365 journeys made by car as driver. These car journeys were included in the pilot analysis of S-H2.6 in addition to the logger data.

Subjective assessment of the hypothesis S-H2.6 can be obtained from the question 4 “Do you think that any of the following will change with your access to the function?”, sub-question xiii “Your time driving without taking a break” of pre-test user uptake questionnaires. The same question is number 5 in the during test questionnaires.

The final analysis of the hypothesis S-H2.6 will be based on long-term logger data, sequential sets of travel diary data and user uptake questionnaires.

Results of Piloting of Logger Data

In the logger data that was available for piloting, there were 57 over 90 minute-long journeys in total, and 24 of them lasted over 2 hours. However, none of these 57 journeys were followed by 5–60 minute long break and then at least 60 minutes of driving to a direction no more different than ±90 degrees from the direction of the preceding journey. Respectively, there were no over 60 minute long journeys that would have been followed by 5–60 minute long break and then at least 60 minutes of driving to a direction no more different than ±90 degrees from the direction of the preceding journey. To eliminate breaks in the logging to be confused with breaks in the driving, also the destination location of the first trip and the origin location of the following trip should have been controlled not to differ too much in distance.

In total 1,365 journeys made by car as driver that were reported to the travel diary included 61 journeys that lasted longer than 90 minutes and 39 of them lasted more than 2 hours. The number of journeys that lasted more than 2.5 hours was 22, and there were 10 over 3 hour long journeys reported in the travel diary to have been driven without a break, the longest journeys lasting 7:40 hours. However, it is possible that some participants have not reported short breaks within long journeys.

There were all together 7 journeys that lasted at least 90 minutes and were followed by 5–60 minute long break and then at least 60 minutes of driving (or first at least 60 minutes of driving and at least 90 minutes of driving after the break). Only 2 journey chains of them were short breaks at Restaurant, cafe or similar. The rest were short work-related stops or short stops at home between two journeys. Thus 2 journeys that
lasted over 90+60 minutes included a 5–60 minute break, and there were 21 at least 150 minutes long journeys without a break. The total lengths of the journeys with a break were 3:31 and 4:10 hours. The proportion of long journeys with a break was consequently 8.7%.

80% of participants assessed that green driving application or speed limit information / speed alert will not change the time that they drive without taking a break. 17% of participants expected a small increase and 3% a small decrease.

**Next Steps with SRQ-2**

- Data will be analysed for all FOTs
- Correlation between user uptake and objective data will be studied, i.e. if those who assessed themselves that they had experienced an impact had an impact in logged data or travel diary data
- Who were those people who had an impact if only some participants had it
- The implications for safety will be analysed
SRQ 3 DOES THE DEVICE CAUSE DISTRACTION

The hypothesis associated with this research question is;

SRQ-3, H3.1. The duration and/or frequency of glances to defined target areas of the visual scene changes

Data analysed to date

Addressing this research questions relies upon DFOT data where eye-tracking equipment and video data can be used to assess the number and frequency of glances to various locations inside the vehicle.

An eye-tracker has been fitted to the vehicle(s) used for the detailed FOTs at Loughborough University as part of (UK-DFOT1) to record head and eye movements. This device operates by processing the images recorded by two cameras mounted on the dashboard in front of the driver in conjunction with the reflection from an infra-red emitter.

DFOT analysis

The following provides a description of the work contributing to the analysis conducted at Loughborough University, UK. Information on the trial design, research questions and methodology can be found in Deliverable D4.3.1 hence no details on this particular part of the study will be covered in this deliverable.

The majority of the information in this section is drawn from the UK-DFOT1 based at Loughborough University. This trial was specifically designed to answer Safety Research SRQ-3 and as such details of this trial are directly relevant. References are also made to other detailed trials from the UK and Spain as these are also being used to support the analysis of SRQ-3.
Data matching

Data provided for the safety analysis from the Loughborough University DFOT comes from two sources; a GPS based on board data logger combined with a video system and a high sensitivity, unobtrusive eye tracking tool. These two data sources are discreet, i.e. they have no automated method of data synchronisation; this has had to be developed and tested in house.

In order to understand the data sources figure 25 shows how the two can be seen diagrammatically. The eye tracking is shown on top with the GPS and video data below and already synchronised (this is automatic within the device). The data streams are shown as different lengths which are common in reality; however both cover the trial start and end points.

Figure 25 – data synchronisation diagram

Within each data stream are known points; in the case of the GPS data these are verified GPS points such as bridges, road junctions or other clear features in the road.
environment. These are verified by GPS mapping and serve as datum points around the trial route.

In the case of the eye tracking data where no location data is recorded (for the point of this example the eye tracking data is recorded without reference to location or time) the points in the data exist as annotation marks added to the data stream when the vehicle passes these known GPS locations during the trial; hence why they are designed to be clear features on the road.

Once the data streams are put together it is clear to see where each annotated point on the eye tracking stream matches up with its corresponding GPS point on the GPS stream. Data can be matched with only one point however in the LU trials the data used three distinct points to mitigate any errors in recording. The points were carefully placed to cover early trial, mid trial and late trial so if data was lost (due to the vehicle being stalled or data recording error) there would still be a salvageable portion with synchronisation marks. Furthermore the points were chosen by vehicle speed as a faster moving vehicle will record fewer identical GPS positions (even at 100Hz sample rate) compared to one which is slow moving or stationary.

Results from trials with three synchronisation points show that the data can be matched to an accuracy of less than 1 second, calculating the location accuracy for all 27 junctions on the LU trial route gives table 4 which shows error in meters.

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<th>GPS Long</th>
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Table 4 – Location errors for manoeuvre start and end points

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<td>27</td>
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<td>-1.125111</td>
<td>2.6</td>
</tr>
<tr>
<td>27</td>
<td>52.693048</td>
<td>-1.126311</td>
<td>2.6</td>
</tr>
</tbody>
</table>

It should be noted that although some of the location errors are around 8 meters the average speeds around the route would indicate that this distance would be covered in significantly less than 1 second.
Data checking and Quality control

Data from the trials were subjected to a number of simple tests to identify areas of interest or concern. The initial data downloads for the trials are huge (>4GB) and include many hundreds of different variables; it is therefore very difficult to get a ‘feel’ for the data through simple text files or other statistical packages.

The proprietary software packages for both the GPS data logger and eye tracker provide useful visualisation tools to assess the quality and completeness of the data; this is good for an early assessment of each data type but does not provide an overall picture of how the combined data will look.

Basic frequencies and visualisations generated through MATLAB provided an early warning for identifying areas that would be worth exploring for the full analysis and those which needed further investigation to understand what the data was showing. For example; a simple plot of eye movement on the X axis (left and right) and Y axis (up and down) (Figure 26) showed a promising avenue for displaying findings; at first glance the plot appears to be show a stationary driver looking at different objects (the grouping of points) however on reflection the graph could also be generated by movement of the head around a stationary object. In this case further analysis of the head movement data needs to be conducted to isolate eye movement.
Figure 26 – eye movement recorded in X and Y

The eye tracking software also allows surfaces within the vehicle to be modelled in 3D. The tool then records gaze intersections with these surfaces. For example, a navigation device within the vehicle can be modelled in the system's ‘world’ and gaze intersections with this surface then recorded in the data. This provides an automated ‘running commentary’ of the areas where the driver is looking. Figure 27 shows the other surfaces modelled within the vehicle, including the instruments and mirrors, and an outside surface, similar to that used in driving simulators which represents the road ahead.
Refinements to this model were on-going during the trials as the type of data visualisation shown above highlighted areas of concern. One area picked up during early analysis was that the driver could in effect look through the bottom or sides of the modelled vehicle and onto the ‘outside’ surface. Obviously this is impossible in the real world and modifications to the 3D model were made to make it impossible in the digital world.

**Verification**

One step removed from data checking and quality control is the verification of the raw data; this process can be summed up as: ‘does the data realistically show what is happening’. This process further enhances the data usability by ensuring that what happened out in the real world is adequately reflected by the numbers in the raw data. This process also boosts confidence in the data and has been used to identify other unexpected events.

At a basic level the data (or more commonly a portion of the data) is viewed in parallel with a visualisation package; either the GPS data logger or the eye tracker package, this process allows individual records in the raw data to be verified against video. Of course compared to the raw data, video is at a much lower frequency and resolution, it also
records continuous data of the scene requiring user input to determine eye gaze or head position compared to the automated and discreet data acquisition tools.

However, and excepting videos limitations, it is hugely valuable to ‘eyeball’ sections of the data. Early analysis of the raw eye tracking data showing a glance to an object in the vehicle is made much more reliable when video data showing the same glance is also available. This technique is not designed to be reversed - adding data to the raw files when a glance is detected solely by video - this is primarily because video files are much more subjective and are best placed to reinforce what the raw data says than to add to it.

This technique has also been used to identify unexpected events and anomalies in the data. As described previously the eye tracker can only record what it sees and with that errors can be expected; each driver is different, each driving position is different and, on each trial, environmental conditions are different. This means that some errors or inconsistencies will be present within the data no matter how careful the calibration process is.

One such inconsistency is the modelling of the navigation device in the eye tracker 3D world coupled with coincidences of road layout and modern vehicle design. To ensure reliable intersections with the 3D model of the navigation device in the software the surface had to be modelled larger than it was in reality – this differed from participant to participant (high eye tracking confidence equating to a smaller surface, low tracking confidence to a larger surface) but consistently remained ~20% larger.

This set-up worked well in relatively controlled environments where the road was straight or there was little roadside infrastructure, however, as the vehicle entered a left hand curve or sat waiting for automated traffic controls to change the drivers gaze often intersected with the model of the navigation device. This artefact of the data was caused by the road geometry leading drivers’ eyes near to where the navigation device was positioned in the vehicle. While they were not directly looking at the device the eye tracking system would record a long and steady glance to the device.

Obviously this data is misleading and needs to be corrected or removed. As such test are conducted to determine areas of the trial route where this can occur, for example; specific left curve radii where eye gaze intersects with the navigation device. This simple
example shows just how important the verification process and ‘eye balling’ the data is to the quality of the data and confidence of the analysts.

**Other data**

SRQ-3 will ultimately not be answered solely by the UK DFOT - other partners’ data will be used providing it meets a few basic requirements.

Identical trial methodologies cannot be expected to be employed by different partners especially if expensive equipment are used such as an eye tracker. A basic data specification was drawn up and liaison with partners during set up for DFOTs ensured that data could be useful to a wider audience.

To answer SRQ-3 a minimum requirement of video data, GPS data and event identification has therefore been stipulated.

**Video data** – This forms the basis of the analysis as basic visual behaviour metrics can be interpreted from a clear, uninterrupted view of a drivers face. Alongside this some knowledge of the positioning of the device (or another video channel on the device to identify activity) was required (see fig XXX). Crucially video also allowed capture of contextual data from front and rear facing cameras.

**GPS data** – A basic set of positional and vehicle based measures was required. These variables include vehicle location (latitude and longitude), speed, acceleration data and, if possible, other vehicle control data such as throttle position, gear position, brake activation etc. Ideally this data was to be synchronised to the video stream.

**Event identification** – One of the crucial elements of SRQ-3 was the determination and rating of events. These events identified areas of interest for analysis, for example; a period/moment where the driver was expected to be distracted due to a command being given by a nomadic device. Once these areas are identified the analysis can be tuned to determine the effect.

Additionally a rating system was used by both LU and MIRA to provide a subjective risk measure for these events. This simply rated the junction or manoeuvre over a 4 point scale based on how hard the driver needed to “concentrate” to stay safe. The rating was intended to record just the external scene (so not including how hard the gear change
was or the difficulty of the navigation system) and ranged from 1; ‘hardly needed to concentrate at all, very simple manoeuvre with no traffic’ right through to 4; ‘Had to concentrate a lot, lots of traffic/pedestrians, multiple lanes, complex junction’

Figure 28 – MIRA DFOT video data

Interim Results

Interim results are presented in the following figures. In figure 29, the average duration of glance behaviour at all junctions with the highest ‘concentration’ rating are shown and the analysis differentiates between novice and baseline SatNav users. As can be seen, the introduction of the SatNav system has an impact on the glance behaviour in that duration of glance to on-road reduces as duration of glance to the SatNav becomes a factor. The numbers of subjects in each group needs to be taken into account, however.
In figure 30, glance behaviour was studied at junctions with the lowest participant concentration rating. As can be seen from the figure, glance duration to the SatNav system is still a factor in the novice-user group but it is not as prominent as in the high-concentration junctions condition.

Overall, there is a major difference between the glance duration for on-road between the novice and base-line conditions and whilst the reasons for this are not clear, the small numbers of subjects needs to be considered.

**Figure 29 Glance Behaviour in UK-DFOT1 (HC Junctions)**
In figures 31 and 32, the glance behaviour is studied at specific road manoeuvres. In this analysis, the manoeuvres which were rated by the participants as requiring the highest and lowest overall concentration were studied. Figure * gives the analysis for junction 7, which the participants rated as requiring the highest overall level of concentration.  It can be seen, the visual behaviour changes such that the participants tended to spend less time looking at the road ahead because they were looking at the SatNav system. It is notable that the time spent by the participants looking at the vehicle interior did not change between the baseline and novice user participants.
Figure 31 - Glance Behaviour in UK-DFOT1 (Manoeuvre 7)

A similar finding was made with regard to the analysis of junctions with the lowest concentration ratings. However in this analysis, it can be seen that there is a difference in the glance behaviour with regard to the vehicle interior.
Next Steps with SRQ-3

The next steps in the data analysis for this research question are as follows;

- Finalisation of glance behaviour for all subjects (baseline/novice/experienced) within the UK DFOT1
- Further analysis of glance behaviour to pinpoint fixations to specific interior and exterior locations (including the nomadic device)
- Manual analysis of video data (from UK DFOT2) to study glance behaviour and the association of this analysis with automated data from the eye-tracker within UK DFOT1.
- Comparison of results from DFOTs in Spain-Valladolid and Greece-Thessaloniki
- Impact assessment and global implications
SRQ 4 IS SPEED AFFECTED

The hypotheses associated with this research question are;

H4.1 The number of speed violations / proportion of time spent in excess of the speed limit changes with the device

H4.2 There is a change in average Speed

SRQ-4, H4.1 The number of speed violations / proportion of time spent in excess of the speed limit changes with the device.

Data analysed to date

The analyses of this hypothesis “S-H4.1 The number of speed violations / proportion of time spent in excess of the speed limit changes with the device” should be based on both travel diary data and data coming from the different data loggers.

The pilot analysis was only based on the Greek logged data where data from 108 participants and one month of driving with the system was available. Information coming from travel diaries was not available.

Results

In the available data file (Greek data), the following set of variables was offered: Date, Time, Longitude, Latitude, Altitude, Azimuth, Speed and Satellites. Thus, not every necessary analysis was possible since some other relevant and necessary variables were not included in it (i.e. Speed limit, Device status -off or on, specifying which functions are in use in the device-, Journey identifier, etc.).

Therefore, analyses on the specific “Number of speed violations / proportion of time spent in excess of speed limit” were not possible at this phase since the calculation of the right indicator could not be computed without the information on the speed limits of the driven roads. Additionally, it was not possible to compare the use of the device and its
different functions to normal driving (without the device), since the information on the device status was also not available.

In the same way, data could not be analysed with reference to each journey since it was not possible to identify journeys or legs in this example data set. To compute journeys, the travel diary information would be needed (to discriminate trips with regard to its aim) and, as far as possible, extra data from the loggers on origins and destinations positions (although this extra data is not always available in TeleFOT loggers being used).

Nevertheless, this initial stage of the analysis has shown a clear need for a new set of variables not currently available. Therefore, the following variables will be considered in the processing:

- time exceeding the speed limits
- proportion of time spent in excess of the speed limit in relation to the journey
- number of violations (exceedences during a journey)

This data will be obtained as derived variables from TeleFOT central database (using the information from the different tests sites together with map matching information) and will be available through the Legs Table. Moreover, different percentages of exceedences will be considered (time spent 10% over the speed limit, time spent 20% over the speed limit, etc.).

**Discussion**

It is important to mention that in this data file (Greek data), a restricted set of variables was offered and thus not every necessary analysis was possible at this stage. Therefore, further analyses should consider extra variables from logged data as well as travel diary data sets in order to explore effects of the different functions used. Therefore, the final analysis of the hypothesis S-H4.1 will be based on long-term logger data and travel diary information.

The planning for the next stage of analyses includes the following:
- An inferential analysis (group comparison and regression analysis) for the proportion of time spent in excess of the speed limit changes in relation to the corresponding functions (namely speed limit information and speed alert).

- An inferential analysis (group comparison and Poisson regression analysis) for the number of violations in a journey with regards to the activation of the functions (namely speed limit information and speed alert).

These analyses would be performed considering several independent variables such as the type of journey (i.e. commuting vs. not commuting), the type of road (i.e. speed limit) and the time of the day/week. Furthermore, the possibility of having driver characteristics into the analyses is still under discussion within the framework of SP4. For this particular RQ, studying personal characteristics could be very valuable since many studies have demonstrated the influence of these aspects on speed behaviour.

**Additional Pilot**

A further independent pilot was carried out by Loughborough University using the most recent ‘legs’ table available from the TeleFOT central server at the time of writing (legs_2010_10.csv). This contained relevant speeding data for two countries but lacked adequate explicit information on whether the device was in use or not. Table 3 shows the duration of speeding in km for each country and suggests significant differences between the countries, at least at first sight. The types of trips undertaken by the sample vehicles are however not necessarily comparable and the apparent result here— that speeding is more frequent in the Swedish sample than the Greek sample—requires careful consideration.

<table>
<thead>
<tr>
<th></th>
<th>Exceeding speed limit (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No</td>
</tr>
<tr>
<td>Greece</td>
<td>1664</td>
</tr>
<tr>
<td>Sweden</td>
<td>499351</td>
</tr>
<tr>
<td>Total</td>
<td>501015</td>
</tr>
</tbody>
</table>

*Table 5; Distance travelled in excess of speed limit (km)*
This simple preliminary result also raises the question of which statistical test is appropriate to apply. The chi-squared test of independence is often applied to 2x2 cross-tabulations but it is required that the items counted be independent of each other. In the case of a single journey with one driver and one vehicle, it would be difficult to argue that the speeding behaviour in one kilometre is independent of the speeding behaviour in the next and therefore it is questionable whether the chi-squared test would be valid. This will be addressed as more data become available and will be reported in the subsequent Deliverable (D4.3.3).

**SRQ-4, H4.2 There is a change in average speed**

- SRQ4 Is speed affected?
  - S-H4.2 There is a change in average speed

- Data analysed:
  - Swedish FOT2 (Navigation, green driving, traffic info – 96 participants)
  - Swedish FOT4 (Traffic info – 300 participants huge drop off)
  - Statistical testing
  - Mann-Whitney or t test depending on whether the distribution could be considered as normal

- **Results – SWE LFOT2 (GD, NAV, TI)**
  - No significant difference for average_velocity_when_driving
  - Trend for average_velocity (p=0.07)
D4.3.4 Impact on Safety – preliminary results

Figure 33- Average velocity in Sweden LFOT2

Significant difference for both average_velocity (p<0.001) and average_velocity_when_driving (p<0.001)

SWEDEN LFOT4 (TI)

Significant difference for both average_velocity (p<0.001) and average_velocity_when_driving (p<0.001)

Figure 33- Average velocity in Sweden LFOT2

Figure 33- Average velocity in Sweden LFOT2
Conclusions

- For SWE LFOT2, there is no significant change in average speed
- In SWE LFOT4 there were significantly different changes in the average speed

Next Steps with SRQ-4

The next steps in the data analysis for this research question are as follows;

- Further analyses of other test sites data (UK, Valladolid-SP, IT, etc.), proceeding to conduct basic analyses at a first step and detailed analyses afterwards considering personal characteristics such as gender, age, etc.

- Comparison analyses among different test sites when possible, focusing on the functions used and their implications on speed behaviour.

- Impact assessment and global implications.
SRQ 5 IS THE VEHICLE POSITIONING AFFECTED (PROXIMITY AND LANE POSITIONING)

The hypotheses associated with this research question are;

H5.1; The longitudinal positioning of the vehicle will change as a result of having the nomadic device

H5.2; The lateral positioning of the vehicle will change as a result of having the nomadic device

SRQ-5, H5.1/H5.2 The longitudinal / lateral position of the vehicle will change as a result of having the nomadic device

Data analysed to date

See table 4 and discussion below. At present the analysis has been performed on Subjective data only due to absence of logged data from the LFOTs. However, analysis of the logged data will be undertaken in the final analysis stage and will be reported in D4.3.2.

Results

Data assessment through:

- **Objective data**;

- **Subjective data** (i.e. perception of the users about the impact of the ND on vehicle lane positioning).

Objective data

Investigation about types and formats of data collected by the DFOTs is in progress in order to evaluate if data are suitable or not to estimate vehicle positioning within the lane during regular vehicle usage and during the concurrent usage of ND.
Data about detailed positioning of vehicles within lane are not available for LFOTs.

Data about vehicle lane positioning (i.e. lane markings and lane deviation) are available at German DFOT.

**Subjective data**

In this analysis, it is possible to investigate the users' perception about the vehicle lane positioning and the impact of the functions upon this positioning.

There are two items in the TeleFOT user-uptake post-questionnaire that are suitable for the analysis as they involved the impact of the functions on lateral and longitudinal vehicle position.

These are "6. Did using the Navigation Support System result in any of the following situations?" (5 points answer scale from "Never" to "Frequently")

- Difficulty positioning the vehicle with respect to lane
- The distance to a vehicle ahead got smaller than acceptable

For both Navigation Static and Speed Alert/Speed Limit information functions, it is anticipated that they don't affect vehicle positioning within the lane when travelling. Maybe vehicle positioning within the lane could be affected during user interaction with the Nomadic Device as a secondary task performed while driving.

**Data Selection, filtering and post processing for analysis**

Questionnaires:

1. Items involving the impact of the function on the lateral and longitudinal vehicle position.
   - Did using the *function result in any of the following situations?" (5 points answer scale from "Never" to "Frequently")
     - Difficulty positioning the vehicle with respect to lane
The distance to a vehicle ahead got smaller than acceptable

2. Users filling-in POST questionnaire.

Statistical Testing

No test of significant difference. Descriptive statistical analysis performed only.

Results for Navigation system

- Did using the Navigation Support System result in any of the following situations?" (5 points answer scale from "Never" to "Frequently")
  - Difficulty positioning the vehicle with respect to lane
  - The distance to a vehicle ahead got smaller than acceptable

Responses from 120 users (all questionnaires filled in).

0 - “Never”

to

4 - “Frequently”

![Median and Mean chart]

<table>
<thead>
<tr>
<th>Difficulty positioning the vehicle with respect to lane</th>
<th>The distance to a vehicle ahead got smaller than acceptable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median: 1.19</td>
<td>Median: 1.00</td>
</tr>
<tr>
<td>Mean: 1.00</td>
<td>Mean: 0.92</td>
</tr>
</tbody>
</table>

5/7/2011
Results for Speed Alert - Speed Information system

- Did using the Navigation Support System result in any of the following situations?" (5 points answer scale from "Never" to "Frequently")
  - Difficulty positioning the vehicle with respect to lane
  - The distance to a vehicle ahead got smaller than acceptable

Responses from 121 users (all questionnaires filled in).
0 - “Never”

4 - “Frequently”

**Figure 37 – Questionnaire Responses Regarding Lane-positioning – Speed Information System**
Figure 38 – Distribution of responses vehicle positioning – Speed Information System

Navigation system distribution

Figures 37 and 38 show the distribution of responses for Navigation (figure 37) and speed information (figure 38). For navigation, the median response with regard to asking the participants about both the ‘difficulty positioning the vehicle with respect to lane’ and the ‘distance to the vehicle ahead’ was ‘almost never’. According to absolute values, users perceived that the Navigation support system very rarely affects vehicle lane positioning, both for lateral and longitudinal vehicle control.

Figure 39 – Statistical Analysis of Responses regarding vehicle positioning - Navigation
Speed Limit information/Alert system

According to absolute values, users perceived that the Speed Alert/Speed Limit information very rarely (almost never) affects vehicle lane positioning, both for lateral and longitudinal vehicle control.

According to distribution of responses, users perceived that the Speed Limit affects vehicle positioning within the lane less than Navigation support system.

![Distribution chart](image)

**Figure 40 – Analysis of Responses regarding vehicle positioning – Speed Information**

**Next Steps with SRQ-3**

- Data will be analysed for all FOTs
- Correlation between subjective data (from questionnaires) and objective data (from DFOTs) will be studied
- The Implications for safety will be established
### D4.3.4 Impact on Safety – preliminary results

**Table 6 – Lateral and Longitudinal position – performance indicators, input parameters and devices for parameters/s recording**

<table>
<thead>
<tr>
<th>Lateral/Longitudinal</th>
<th>Performance indicator</th>
<th>Input parameter(s)</th>
<th>Indicator description</th>
<th>Device for parameter(s) recording</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lateral</td>
<td>HFC (High Frequency Component of steering angle)</td>
<td>Steering angle position (deg, rad)</td>
<td>Ratio between high frequency steering components (above 0.3Hz) and steering components having frequencies between DC and 0.6Hz as bandwidth: the number of corrections during the experimental phase measured by means of HFS should be compared to the corrections during the control.</td>
<td>Steering wheel encoder</td>
</tr>
<tr>
<td></td>
<td>Steering Entropy</td>
<td></td>
<td>It is computed on the basis of prediction errors of steering signals. The predictions are obtained by applying a predictive filter on the steering signal. Usually, the predictions are obtained by performing a second-order Taylor expansion using the samples at the three previous time steps. The entropy of the signal is then calculated on the basis of the distribution of these errors.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Steering Reversal Rate</td>
<td></td>
<td>The number of changes in steering wheel direction per minute (turns/minute).</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Steering Action Rate</td>
<td></td>
<td>The number of steering wheel movements per second faster than a threshold velocity</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Standard deviation of Lateral Position (and mean lateral position)</td>
<td></td>
<td>Standard deviation of Lateral Position (and mean lateral position)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lane exceedence (LANEX)</td>
<td></td>
<td>Proportion of time a defined part of the vehicle is outside the lane boundary</td>
<td>Lane departure warning (or cameras and imaging algorithms recording vehicle distance to the lanes)</td>
</tr>
<tr>
<td></td>
<td>Mean of Time to Lane Crossing minima</td>
<td>Lateral distance to the lane(s)</td>
<td>The mean of the local minima in the Time to Line Crossing signal</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Minimum Time to Line Crossing</td>
<td></td>
<td>The minimum values of the time-to-collision (TLC) signal in a time frame</td>
<td></td>
</tr>
<tr>
<td></td>
<td>% of TLC under a threshold</td>
<td></td>
<td>% of time the TLC is under a defined threshold</td>
<td></td>
</tr>
<tr>
<td>Longitudinal</td>
<td>Deceleration Jerks (DJ)</td>
<td>Vehicle speed or vehicle acceleration</td>
<td>The number of occurrences of a deceleration change higher than 10 m/s^2, induced by braking. The applied measure is the number of abrupt onsets of brakes per distance or time range</td>
<td>Speedometer</td>
</tr>
<tr>
<td></td>
<td>Mean of Time to Lane Crossing minima</td>
<td>Distance between the vehicle and the obstacle ahead (m)</td>
<td>The mean of the local minima in the Time to Collision signal</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Minimum Time to Line Crossing</td>
<td>Speed of the obstacle (km/h)</td>
<td>The minimum values of the time-to-collision (TTC) signal in a time frame. TTC is the ratio between the relative distance of the 2 vehicles and difference of their speeds.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>% of TLC under a threshold</td>
<td>% of time the TTC is under a defined threshold</td>
<td>% of time the Time Headway is under a defined threshold</td>
<td>Radar/Lidar</td>
</tr>
<tr>
<td></td>
<td>Minimum Time Headway</td>
<td>Distance between the vehicle and the obstacle ahead (m)</td>
<td>The minimum values of the time headway signal in a time frame. Time Headway is the ratio between the relative distance of the 2 vehicles and the speed of the following vehicle.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mean of Time Headway minima</td>
<td>Speed of the following vehicle (km/h)</td>
<td>The mean of the local minima in the Time Headway signal</td>
<td></td>
</tr>
<tr>
<td></td>
<td>% of Time Headway under a threshold</td>
<td>% of time the Time Headway is under a defined threshold</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
SRQ 6 IS BRAKING AFFECTED

The hypothesis associated with this research question is

SRQ-6, H6.1 The device changes braking behaviour

The braking behaviour might be influenced in various ways due to a function of a nomadic device. One possible finding could be that, with the support of a green driving application, the driver strives to avoid a stop at a red light and tries to roll out until the traffic light turns green again. If the traffic light is still red, the driver has to brake anyway. That might be later, but coincidentally harder to come to a stop at the red light. Another outcome from the analysis regarding the above mentioned hypothesis might be that the driver brakes less with the help of speed limit information, because he is always aware of the current speed limit.

Data analysed to date

The analysis described here are the preliminary results from the first sets of data from the German DFOT and the UK DFOT2. Further extensive analyses of data will be conducted when the full FOT data from all test-sites are available for analysis.

The analysis presented here is based upon logged data which is mostly brake pressure and/or deceleration. The functions of the nomadic device, which is used in the German DFOT, are static navigation, speed limit information and speed alert as a bundle. The UK DFOT2 uses a smart phone application, named FootLite, which provides a green driving support and additionally forward collision warning.

Every test subject (8 of 12) of the German DFOT, who completed the whole DFOT, i.e. who has driven all configurations, has been considered for this analysis (experimental design of German DFOT described in D3.6.1). For the UK DFOT2, every driver with a baseline and a treatment journey has been considered for the analysis.

Results

Bundle: NAV, SI/SA (German DFOT)

It has been evaluated, how often and how hard the driver applies the brake pedal. Therefore, the deceleration is evaluated after the driver applies the brake pedal. Thereby,
it can be shown if there are more braking manoeuvres and with which intensity with the influence of a function. The deceleration has been divided into five ranges (2 m/s² - 3 m/s²; 3 m/s² - 4 m/s²; 4 m/s² - 5 m/s²; 5 m/s² - 6 m/s²; 6 m/s² - 7 m/s²). The data of eight test subjects (approx. 1260 km/driver) has been analysed by now.

The statistical testing (two-way ANOVA) shows no statistical significant influence on the intensity of the braking manoeuvres, but a statistical significance could be noticed between the different configurations. In configuration A, the driver is supported by the functions of the nomadic device which are static navigation, speed limit information and speed alert as a bundle. In configuration B, the driver is supported by three advanced driver assistance systems (ADAS) which are adaptive cruise control (ACC), forward collision warning (FCW) and lane keeping assistant (LKA). The third configuration (C) supports the driver with both, the functions of the nomadic device and ADAS. Between configuration A and B and between configuration A and C, a statistical significant increase of braking manoeuvres could be noticed (Figure 42).

![Amount of braking manoeuvres](Figure 42 - Absolute amount of braking manoeuvres of 8 test subjects with three configurations: A, B and C)

Since there is only a statistical significance between configuration A and B and between A and C, it is ambitious to say that there is an influence of the nomadic device with its
functions, because in configuration B the device has not been used, but in configuration C. To approve this fact, a more detailed analysis is currently ongoing.

**FootLite (UK DFOT2)**

Nearly the same approach has been used to analyse the influence of the FootLite system. Since no brake pressure signal is available, only the deceleration value can be assessed to find braking manoeuvres. In this DFOT, there are no braking actions with more than 4 m/s², therefore only two sections are taken into account (2 m/s² - 3 m/s², 3 m/s² - 4 m/s²). Figure 43 depicts the absolute amount of braking manoeuvres of 28 drivers on the defined route of UK DFOT2 divided into two deceleration ranges. More details of the route and the experimental design can be found in Deliverable D3.6.1. The results of the statistical testing (two-way ANOVA) show that neither the overall amount of braking manoeuvres increases significantly nor each range itself.

![Figure 43 - Amount of braking manoeuvres during control condition (CON) and during treatment phase (FL)](image)

**Next Steps**

In this first approach, the trips are considered as a whole without paying attention to any environmental influences like length of the trips, different road types, different speed limits, possible construction sites, etc. This will be done in the ongoing analysis in order to come to a deeper understanding of the functions and their influence on the braking behaviour of the test subjects.
Besides this, other DFOT data which can support this research question will be analysed in the same manner to get a best possible covering of all test sites.
SRQ 7 IS NON-DRIVING MANUAL ACTIVITY AFFECTED

The hypothesis associated with this research question is;

**SRQ-7, H7.1 There is a change in the duration of hands off wheel time.**

The philosophy behind this research question was to investigate how much drivers take their hand(s) off the wheel to do things in the car that are not part of the primary driving activity (e.g. control nomadic device, change radio, etc..). This is considered with the assumption that increased hand(s) off wheel time implies decreased safety (especially if it can be related to increased eyes off road time or confidently used as a surrogate for this).

**Data analysed to date**

After a preliminary analysis of the different potential source of data, considering the available type of sensors and logged data it was decided to focus the analysis on the video data collected in the Italian DFOT. In fact some data loggers in the LFOT provide information relating to the frequency of operations activated manually on the device, but this does not give information on the general manual activity aside from operating the device.

Concerning the Italian DFOT, a rather detailed description of the setup of the on-board setup and data analysis tool used is reported in the deliverable D3.6.1 “Detailed FOT execution”. Two cameras were mounted for recording the eyes and the hand of the drivers during the Test. The test was a controlled one, based on a mixed urban and highway route driven two times in order to collect baseline and active functions data. Three functions were activated in different stretch of the route: Navigation, Green Driving and Traffic Info.
The data-set of 49 participants were collected including vehicle dynamic parameters, “eyes” video and “hands” video. The CANApe tool by Vector was used both for acquisition and analysis. It provides a “parallel” analysis capability allowing displaying synchronized data and video windows (figure 43 above).

The analysis was then performed manually looking for “hands off the steering wheel” situations and correspondingly verifying the reason (due or not due to the active function at the considered instant). This process is quite time consuming, for this reason it is still on-going; up to now about 20% of the available data (11 participants) have been analysed.

The overall process may be summarized in the following steps:

- Selection of video parts for the different functions.
- Detection/measurement of quantity, duration, type of periods with “hands off steering wheel”.
- Comparison of the measured times for the different functions and the baseline.
- Significance analysis.
Results

Considering the data so far analysed the only apparent difference between baseline and active functions is due to the interaction with the system when a Traffic Information is signalled and the driver decides to accept a change of route pressing the PND display (figure 44).

The total time of “hands off steering wheel” employed for this operation varies from 2 to 5 seconds (left hand used). The good point is that the analysed participants respected the instruction of programming a new route on the navigator only when the vehicle is stopped. Also, up to now, no setting option change (2d-3d vision, volume, zoom,.....) have been detected.

On the contrary a number of other non-driving operations while the vehicle is moving have been detected:

- Cellular phone consultation/setting.
- Driving with the right hand placed on the gearshift lever. This is quite a frequent habit.
- On board multimedia system control (even if for some operations steering buttons where available) (figure 44)
- Paper instructions consultation (figure 44).
- Air conditioning system regulation.

![Figure 44 - shots of “hands off steering wheel” situations:](image)

a) left - Confirmation of recalculation after traffic information; b) centre - Radio regulation; c) right - Document consultation.
Discussion

The preliminary results seem to demonstrate that the use of the functions has a very low impact on “hands off steering wheel”, especially if compared with other operations that drivers normally perform while driving.

The fact that paper instruction consultation with vehicle in movement was detected could be considered a point in favour of navigation support, because in the “pre navigators” era it was quite frequent to see drivers consulting maps on their legs or in one hand while driving.

Next Steps

In the next period the analysis of the other participants’ data will be performed in order to assess the evaluation also from a statistical viewpoint. Moreover, a classification and quantification of the different “non-driving” operation will be performed.
CONCLUSIONS

- This deliverable shows that there has been good progress in WP4.3 since the draft analysis plans were developed.

- Where possible interim analyses have been carried out. These have used mainly LFOT data although an example showing how the UKDFOT data will be used to assess distraction has also been possible.

- The analyses carried out to date have shown that most of the relevant variables required in order to undertake the analyses of LFOT data were available in the central database. However, there is still some work to do with regard to map-matching, speed calculations and the identification of when a system is in use.

- In general, there is confidence that each of the RQs 1-6 and associated hypotheses can be answered and will give some meaningful results. It is still not clear whether suitable data are being collected for answering SRQ7.

- It has yet to be established the extent to which an assessment of the global impact will be possible. This will be determined once the data from all FOTs are available and the sample sizes relating to each function and across the different regions in Europe is fully identified. The representativeness can then be considered in relation to making predictions for national, European or indeed global impacts.
## ANNEX 1 DATA PROVISION AND RESEARCH QUESTION RESPONSIBILITIES

### Large-Scale FOTs – Safety Research Question Responsibilities

<table>
<thead>
<tr>
<th>Partner</th>
<th>Member State</th>
<th>FOT</th>
<th>Device name (if relevant)</th>
<th>Function to be tested</th>
<th>$S_1$ - Is the route where travel takes place affected?</th>
<th>$S_2$ - Is the amount of time on the road affected (how long travel takes place)?</th>
<th>$S_3$ - Does the device cause distraction?</th>
<th>$S_4$ - Is speed affected?</th>
<th>$S_5$ - Is vehicle positioning affected (proximity and lane position)?</th>
<th>$S_6$ - Is braking affected?</th>
<th>$S_7$ - Is non driving manual activity affected?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loughborough/MIRA</td>
<td>UK</td>
<td>LFOT1</td>
<td>Blom</td>
<td>Blom navigation</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loughborough/MIRA</td>
<td>UK</td>
<td>LFOT2</td>
<td>MobiEye</td>
<td>FCW/LDW</td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
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</tr>
<tr>
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<td>Spain Madrid</td>
<td>LFOT1</td>
<td>Blom</td>
<td>SLI, speed alert, navigation (static), speed camera alert</td>
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<td></td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>ETRA</td>
<td>Spain Madrid</td>
<td>LFOT1</td>
<td>ecoNAV</td>
<td>Traffic info, speed limit info, green driving support</td>
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<td>x</td>
<td>x</td>
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<td></td>
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<td>LFOT1</td>
<td>Blom</td>
<td>SLI, speed alert, nav support (static)</td>
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<td></td>
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<td>SLI</td>
<td>SLI, speed alert, green driving support</td>
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<td>x</td>
<td>x</td>
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<td>Navigation support (static), green driving</td>
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<td>x</td>
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<tr>
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<td>Sweden</td>
<td>LFOT4</td>
<td>Traffic info</td>
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<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
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<td></td>
<td></td>
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<tr>
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<td>Finland</td>
<td>LFOT1</td>
<td>Green driving, speed alert</td>
<td></td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
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<td>France</td>
<td>LFOT1</td>
<td>eCall alerts system</td>
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<td></td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
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<td>Greece</td>
<td>LFOT1</td>
<td>Samsung OMNIA II / Telenav-Sygic</td>
<td>nav support (static)</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
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<td>x</td>
</tr>
<tr>
<td>ICCS</td>
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<td>LFOT2</td>
<td>Samsung OMNIA II / Telenav-Sygic</td>
<td>Nav support (static), SLI</td>
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<td>x</td>
<td>x</td>
<td>x</td>
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<td></td>
<td>x</td>
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<td>ICCS</td>
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<td>LFOT3</td>
<td>Samsung OMNIA II / Telenav-Sygic</td>
<td>Nav support (static), Traffic info</td>
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<td>x</td>
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<td>x</td>
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<tr>
<td>ICCS</td>
<td>Greece</td>
<td>LFOT4</td>
<td>Samsung OMNIA II / Telenav-Sygic</td>
<td>Nav support (static), speed alert</td>
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<td>x</td>
<td>x</td>
<td>x</td>
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</table>

Partner responsible for leading the research question: CHA, VTT, LOU, CID, UNIM, IKA, CRF
Detailed FOTs – Safety Research Question Responsibilities

| Partner      | Member State | FOT  | Device name (if relevant) | Function to be tested | $S1$ - Is the route affected where travel takes place? | $S2$ - Is the amount of time spent traveling affected? | $S3$ - Can the device cause distraction? | $S4$ - Is speed affected? | $S5$ - Is vehicle positioning affected? | $S6$ - Is braking affected? | $S7$ - Are warning devices in manual control? |
|--------------|--------------|------|---------------------------|-----------------------|----------------------------------------------------|------------------------------------------------|--------------------------------|------------------|--------------------------------|------------------|--------------------------------|------------------|
| VTT          | Finland      | DFOT1| CAA                       | Visual behaviour assessment/ADAS | x                                                  | x                                              | x                                          | x                | x                                             | x                | x                                             |
| VTT          | Finland      | DFOT2| eCall                     | eCall receiving and handling in PSAP | x                                                  | x                                              | x                                          | x                | x                                             | x                | x                                             |
| VTT          | Finland      | DFOT3| Several                   | Navigation (bench-marking tests) | x                                                  | x                                              | x                                          | x                | x                                             | x                | x                                             |
| VTT          | Finland      | DFOT4| TeleISA                   | Speed alert and speed limit information | x                                                  | x                                              | x                                          | x                | x                                             | x                | x                                             |
| Loughborough | UK           | DFOT1| Blom                      | Navigation/Speed Alert | x                                                  | x                                              | x                                          | x                | x                                             | x                | x                                             |
| Loughborough | UK           | DFOT2| FOOTLTE                   | Green Driving Advisor   | x                                                  | x                                              | x                                          | x                | x                                             | x                | x                                             |
| Loughborough | UK           | DFOT3| MobileEye                 | Forward Collision Warning/Lane Keeping Assist     | x                                                  | x                                              | x                                          | x                | x                                             | x                | x                                             |
| IKA          | Germany      | DFOT1| All                       | Navigation support/speed limit info/speed alert/LKA/FCW/ACC | x                                                  | x                                              | x                                          | x                | x                                             | x                | x                                             |
| Cidet         | Spain        | DFOT | Blom                      | Navigation (FOT under development)               | x                                                  | x                                              | x                                          | x                | x                                             | x                | x                                             |
| CRF/MM       | Italy        | DFOT |                           | Navigation                        | x                                                  | x                                              | x                                          | x                | x                                             | x                | x                                             |
| ICSS/CERTH   | Greece       | DFOT1|                           | Navigation support (static), ADAS (CAS, LDW)     | x                                                  | x                                              | x                                          | x                | x                                             | x                | x                                             |
| ICSS/CERTH   | Greece       | DFOT2|                           | Speed limit info, navigation support, ADAS (CAS, LDW) | x                                                  | x                                              | x                                          | x                | x                                             | x                | x                                             |
| ICSS/CERTH   | Greece       | DFOT3|                           | Traffic information, navigation support, ADAS (CAS, LDW) | x                                                  | x                                              | x                                          | x                | x                                             | x                | x                                             |
| ICSS/CERTH   | Greece       | DFOT4|                           | Speed alert, navigation support, ADAS (CAS, LDW)  | x                                                  | x                                              | x                                          | x                | x                                             | x                | x                                             |

Partner responsible for leading the research question: CHA, VTT, LGU, CID, UNIM, IKA, CRF
REFERENCES


Appendix 1 - TeleBUS Results on Speeding Paper
Presented at ITS World Congress, October 2011

Impacts of Green Driving Application in City Buses

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Abstract

As part of TeleFOT project, the impacts of a green driving application were assessed in city bus traffic. Specifically, the purpose of the study was to assess the impacts on fuel consumption, speeding and passenger comfort. Nobina city bus drivers of frequently operated Jokeri route in Helsinki metropolitan area were the test subjects of the study. The main result of the study was that the use of green driving application reduces the fuel consumption and speeding significantly. New users of the system drove more economically than those who had used it longer. The fuel saving of the new users was in peak traffic 2.7 l/100 km for whole route and even 5.4 l/100 km for one section. In addition to fuel saving, the green driving application encouraged to drive according to the speed limit. Consequently, the main conclusion was that the use of a green driving application is beneficial even after years of use for reducing both fuel consumption and speeding. It is recommended that the drivers are regularly reminded of the use of system and to include green driving to the driver trainings.

Keywords:
Green driving, eco-driving, city buses, impact assessment, fuel consumption, speeding
Introduction

Background

Road transport CO₂ emissions form an important component of greenhouse gas generated in most developed countries. Among the policy options to reduce these emissions is eco-driving. Reducing fuel consumption significantly by teaching drivers how to change their driving behaviour is potentially a very cost-efficient way to reduce energy use and emissions [1].

The green driving application or the eco-driver assistance aims at assisting and encouraging the driver to drive more economically. This is done by providing the driver information about the fuel consumption, energy-use efficiency, appropriate gear selection, acceleration or speed. Numerous studies have looked at the short-term impact of eco-driving on fuel consumption. Johansson et al [2] summarised several sources in 2003 and concluded that the education in eco driving reduces the fuel consumption by 5–10%. For OECD an average 5% reduction was assessed based on an expert analysis of available literature [1]. For EU27, it has been assessed that eco-driver assistance systems could reduce CO₂ emissions by 5–15% if the penetration of such system and the driver compliance were both 100% [3].

The fuel consumption and mileage of buses is higher than of passenger cars. Consequently, the potential of green driving or eco-driving applications on buses is of interest. Wahlberg [4] monitored fuel consumption reduction in busses and recorded 2% fuel savings during the 12 months after training. In Athens, fuel savings on busses of 4.35% per km during a post training monitoring period of two months were found [5]. Both studies report, however, that after a time drivers partially slip back to less environmentally friendly driving habits resulting in lower fuel savings than originally attributed to the courses. However, even this 4.35% reduction resulted annual fuel savings of 1 697 € per bus [5].

Purpose
Since 2004 VTT Technical research Centre of Finland has been developing an active real-time operating green driving application “RASTU” which guides the bus driver to drive the more energy-efficient (or fuel-efficient) way (Figure 1). The system includes location information and it has the information on the bus route and timetable. The system guides drivers in economical driving, taking into account the quality of service, vehicle position compared to the scheduled position and the passengers' traveling comfort.

**Recommendation on intensity of acceleration:**
Green (throttle ok), yellow (throttle more), red (throttle back)

**Current speed and its relation to the target speed:**
Green (speed ok), red (speeding)

**Target speed (related to the speed limit and timetable)**

Figure 1 - Overview of the HMI of the green driving application

The impacts of the RASTU green driving application were assessed in Helsinki metropolitan area. Specifically, the purpose of the study was to assess the impacts on fuel consumption, speeding and passenger comfort in city bus traffic.

**Methods**
Nobina city bus drivers of frequently operated Jokeri route (Figure 2) in Helsinki metropolitan area were the test subjects of the study. During the study, there were 15 Jokeri buses (diesel buses) with RASTU green driving application and CAN bus logger. Jokeri line is frequently operated regional cross traffic route with about 56 minutes total duration (46 to 65 minutes). During peak hours, buses operate every 5 minutes, at day time every 10 minutes and in the evenings and on weekends every 20–30 minutes. The route is 27 km long. For the analyses, the route was divided into six sections according to number of stops and traffic lights, speed limit and traffic volume (Figure 2).

Drivers were able to access and use the green driving application only after a specific training. Data of altogether 143 Jokeri drivers were analysed in the study. Ten of them were trained to use the application in 2008 or 2009, and 13 of them in spring 2011 (application activated in May 2011). The rest of the drivers belonged to the reference group in the study.

Study was based on logger data collected from June 2010 till September 2011 (16 months in total). Weekends were excluded from the data used in the impact assessment. In addition, those legs with clear errors in data were excluded from the data. Data was divided into three categories: peak traffic, day time traffic and night time traffic according to traffic situation. Data was also divided to summer time and winter time data. Finally, the impact assessment included data of 17 590 runs for the whole route and 13 063–19 120 runs for the individual sections.

Figure 2 - Jokeri line in Helsinki metropolitan area divided into six sections [6]
The passengers of Jokeri line were interviewed on their satisfaction using a questionnaire both on those routes driven by drivers that were using the green driving application and for those that did not have it. Passenger satisfaction assessment was based on 871 filled questionnaires.

**Results**

**Fuel consumption**

The average fuel consumption on Jokeri route was 44.9 l/100 km. The consumption varied for individual sections from 35.5 l/100 km (section 2) to 51.7 l/100 km (section 5). In wintertime the fuel consumption was on the average 2.8 l/100 km higher than in summer time. The consumption was smallest in night time traffic (39.0 l/100 km for whole route) and greatest in peak traffic (46.9 l/100 km).

When studying those drivers for whom the green driving application was activated in 2008 or 2009, it was seen that the fuel consumption in night time traffic was 1.0–1.1 l/100 km smaller for the whole route and in peak traffic 0.2–0.8 l/100 km smaller when they were using the application compared to driving without it (Table 1, row 1). The impact was greatest in summer time for sections 4 and 6 in night time traffic: 4.3–4.6 l/100 km.

<table>
<thead>
<tr>
<th>Drivers Use of system</th>
<th>Summertime</th>
<th>Wintertime</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Night time</td>
</tr>
<tr>
<td>App. activated in</td>
<td>Without vs.</td>
<td>-1.1</td>
</tr>
</tbody>
</table>

Table 1 – Summary of impacts in fuel consumption (l/100 km), whole route. Statistically significant results marked ** = p<0.05 and * = p<0.1. Negative value = smaller consumption with the device or for drivers who have used the device (longer).
When comparing those drivers for whom the green driving application was activated in 2008 or 2009 when they were driving without the application to those drivers who have never access to it, it was seen that in day time traffic that the former (trained) drivers drove statistically significantly more economically than the latter (non-trained) drivers (fuel saving 0.9–1.5 l/100 km for the whole route depending on season, Table 1, row 2). In night time traffic and peak traffic the result was alike but not as clear as in day time traffic.

Those drivers for whom the green driving application was activated in spring 2011 drove statistically significantly more ecologically (fuel saving 1.4–2.7 l/100 km on whole route, Table 1, row 3) in all traffic situations when the application was active when comparing to driving without it. The impact was greatest on sections 5 and 6 (fuel saving 2.9–5.4 l/100 km depending on traffic situation).
Those drivers for whom the green driving application was activated in spring 2011 drove after the first activation of the application also without its assistance more ecologically than before it was first activated. The fuel saving was greatest and statistically significant for whole route in day time traffic (1.4 l/100 km, Table 1, row 4).

When drivers for whom the green driving application was activated in 2008 or 2009 were compared with drivers for whom it was activated in spring 2011 it was seen that the latter group (later trained) drove statistically significantly more ecologically than the former group when they were assisted by the application. Difference in fuel consumption was 1.9–2.4 l/100 km on whole route (Table 1, row 5). There was no clear difference between the groups when the application was not in use (Table 1, row 6).

**Speeding**

On average, the proportion of journey on Jokeri route when the driver was speeding 6–10 km/h was 12% in summertime and 10% in wintertime. Corresponding proportions for over 10 km/h speeding were 7% in summertime and 6% in wintertime. Speeding was most common on section 4 with mostly 40 km/h speed limit in residential area. In summertime, the speeding was most common in night time; however, there was no clear distinction between traffic situations in wintertime.

When studying the drivers for whom the green driving application was activated in 2008 or 2009, it was seen that the 6–10 km/h speeding in the night time was statistically significantly less common when the application was used (on the average 3.5% of journey in summertime and wintertime for the whole route) compared to when it was not used (12.2% of journey in summertime and 10.6% in wintertime). Consequently, the impact of using the device in night time traffic was a reduction of 8.7% in speeding of 6–10 km/h in summertime and 7.1% in wintertime for the whole route (Table 2).

**Table 2 – Impact in % of journey speeding of drivers for whom the green driving application was activated in 2008 or 2009 comparing use of system vs.**
not using the system, whole route. Statistically significant results marked ** = p<0.05 and * = p<0.1. Negative value = less speeding with the device.

<table>
<thead>
<tr>
<th></th>
<th>6–10 km/h speeding</th>
<th>Over 10 km/h speeding</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Summertime</td>
<td>Wintertime</td>
</tr>
<tr>
<td>Night time</td>
<td>-8.7  **</td>
<td>-7.1  **</td>
</tr>
<tr>
<td>Day time</td>
<td>-3.9  **</td>
<td>-2.7  **</td>
</tr>
<tr>
<td>Peak</td>
<td>-2.4  **</td>
<td>-1.9  **</td>
</tr>
</tbody>
</table>

In the day time traffic, the level of speeding 6–10 km/h was similar to night time when the device was not in use (12.3% of journey in summertime and 9.7% of journey in wintertime). However, the impact of using the device was smaller: a reduction of 3.9% and 2.7% of journey in 6–10 km/h speeding respectively (Table 2). In peak traffic, the reduction due to using the device was the smallest: 2.4% of journey in summertime and 1.9% of journey in wintertime. All the results were statistically significant.

The reductions in speeding over 10 km/h due to using the device were quite alike compared to reduction of speeding of 6–10 km/h: 8.2% of journey (in summertime) and 5.8% of journey (in wintertime) in night time traffic, 3.8% and 1.6% of journey in day time traffic, and 1.2% and 1.1% of journey in peak traffic (Table 2).

When comparing those drivers for whom the green driving application was activated in 2008 or 2009 driving without the application to those drivers who had never access to it, it was seen that the former group (trained ones) had less 6–10 km/h speeding (0.5%–1.2% of journey difference depending on traffic situation and season, Table 3) than the latter group (non-trained) but for the over 10 km/h speeding the situation was partly vice versa (-1.6%–0.7% of journey difference). However, it must be noted that the absolute differences were small.
Table 3 – Impact in % of journey speeding of drivers for whom the green driving application was activated in 2008 or 2009 when they were not using the device compared to drivers who have no access to the system, whole route. Statistically significant results marked ** = p<0.05 and * = p<0.1. Negative value = less speeding for drivers who have used the device.

<table>
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<th>Over 10 km/h speeding</th>
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<td>-0.5</td>
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<tr>
<td>Day time</td>
<td>-0.5 *</td>
<td>-1.2 **</td>
</tr>
<tr>
<td>Peak</td>
<td>-1.0 **</td>
<td>-0.9 **</td>
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</table>

Those drivers for whom the green driving application was activated in spring 2011 were speeding (6–10 km/h) 8.5% less for the whole route when using the device compared to when not using it in night time traffic in summer (Table 4). The respective reduction was 3.8%–3.9% in day time traffic and peak traffic. For over 10 km/h speeding, the results were quite alike: a reduction of 5.4% of journey for the night time and 3.4%–3.6% of journey for the day time and peak traffic. All results were statistically significant.
Table 4 – Impact in % of journey speeding of drivers for whom the green driving application was activated in spring 2011, whole route. Statistically significant results marked ** = p<0.05 and * = p<0.1. Negative value = less speeding with the device or after the activation.

<table>
<thead>
<tr>
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<th>Without the device, before vs. after</th>
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</thead>
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<tr>
<td></td>
<td>6–10 km/h speeding</td>
<td>Over 10 km/h speeding</td>
</tr>
<tr>
<td></td>
<td>6–10 km/h speeding</td>
<td>Over 10 km/h speeding</td>
</tr>
<tr>
<td>Night time</td>
<td>-8.5 **</td>
<td>-5.4 **</td>
</tr>
<tr>
<td></td>
<td>-1.0</td>
<td>-0.4</td>
</tr>
<tr>
<td>Day time</td>
<td>-3.9 **</td>
<td>-3.6 **</td>
</tr>
<tr>
<td></td>
<td>-2.4 **</td>
<td>-1.6 **</td>
</tr>
<tr>
<td>Peak</td>
<td>-3.8 **</td>
<td>-3.4 **</td>
</tr>
<tr>
<td></td>
<td>-2.6 **</td>
<td>-1.6 *</td>
</tr>
</tbody>
</table>

When comparing their driving without the device before and after the first activation of the green driving application these drivers drove 2.4%–2.6% of journey less speeding 6–10 km/h in day time traffic and peak traffic after the activation of the application compared to time before that (results statistically significant, Table 4). In night time the impact was 1.0% of journey for the whole route. For over 10 km/h speeding, the results were smaller: a reduction of 1.6% of journey for the day time and peak traffic (statistically significant) and 0.4% of journey for the night time.

When drivers for whom the green driving application was activated in 2008 or 2009 were compared with drivers for whom it was activated in spring 2011 it was seen that the latter (later trained) group were speeding less than the former group when using the device (Table 5). However, the absolute differences between the groups were small. The result was similar also when these two groups drove without using the device.
Table 5 – Impact in % of journey speeding of drivers for whom the green driving application was activated in 2008 or 2009 compared to those for whom is was activated in spring 2011, whole route. Statistically significant results marked ** = p<0.05 and * = p<0.1. Negative value = less speeding for drivers for whom the application was activated in 2008 or 2009.

<table>
<thead>
<tr>
<th>Summertime</th>
<th>With the device</th>
<th>Without the device</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6–10 km/h speeding</td>
<td>Over 10 km/h speeding</td>
</tr>
<tr>
<td>Night time</td>
<td>-0.9</td>
<td>-0.2</td>
</tr>
<tr>
<td>Day time</td>
<td>1.2 *</td>
<td>2.7 **</td>
</tr>
<tr>
<td>Peak</td>
<td>2.3 **</td>
<td>2.7 **</td>
</tr>
</tbody>
</table>

**Passenger satisfaction**

The passengers of those drivers who used the green driving application gave statistically significantly better grades in the passenger satisfaction questionnaire for driver’s willingness to be of service and for decelerations in the peak traffic (Figure 3). The difference was not statistically significant for keeping to timetables although the order was the same. In the day time traffic the differences were not statistically significant.
The purpose of TeleFOT was to study with the large field experiments the impact of nomadic and after-market devices as well as services offered through them. The purpose of this detailed field operational test was to assess the impacts of a green driving application developed at VTT on fuel consumption, speeding and passenger satisfaction. Nobina city bus drivers of frequently operated Jokeri route in Helsinki metropolitan area were the test subjects of the study.

The main result of the study was that the use of green driving application reduces the fuel consumption and speeding significantly. When the drivers who we trained to use the green driving application in 2008 or 2009 had the application active their fuel consumption was on one section of the route even 4.6 l/100 km smaller than when they drove without it. The difference for the whole route was greatest in night time traffic (1.0–1.1 l/100 km). The fuel saving was even greater for those drivers who were trained
to use the system in spring 2011: in peak traffic 2.7 l/100 km for whole route and even 5.4 l/100 km for one section. For both driver groups the impact was seen also on those journeys when they drove without the green driving application as they drove more economically than those drivers who had never access to the system. The greatest statistically significant difference was seen for drivers who were trained to use the system in spring 2011. Their fuel consumption after they had started to use the system for those journeys when they did not use it was in day time traffic 1.4 l/100 km smaller for the whole route than before the green driving application was first activated for them.

In addition to fuel saving, the green driving application encouraged to drive according to the speed limit. When drivers drove the green driving system active they had less 6–10 km/h speeding and over 10 km/h speeding than when they drove without the system or before it was activated for the first time. The green driving application was most beneficial in reducing speeding in areas with low speed limits and in night time. Those drivers who were trained to use the system in 2008 or 2009 were speeding 12.2% of journey (6–10 km/h) in summer time in night time traffic when they drove without the green driving application and 3.5% of journey when they drove with the system activated. These proportions were 9.7% of journey without the system and 1.5% of journey with it for over 10 km/h speeding. The results were in similar also for drivers trained to use the system in spring 2011. When driving without the system those drivers who were trained to use the system did not differ significantly in speeding behaviour from drivers who had never access to the system.

It was confirmed that the results above were purely impacts of using the green driving application because on those journeys driven with the system activated the driving speed was closer to the speed recommendation given by the system than on those journeys when the system was deactivated. The results of up to 10% reduction in fuel consumption were in line with earlier studies. In addition, the novelty effect resulting stronger impacts for new users of the green driving application was confirmed.

The main conclusion was that the use of a green driving application is beneficial even after years of use for reducing both fuel consumption and speeding. The use of green driving application can also have transfer effect, it teaches how to drive more economically also when driving without the system. However, the difference to the actual use of system was clear. Speeding behaviour without the use of system corresponded to
those who had never used the system. It is recommended that the drivers are regularly
reminded of the use of system and to include green driving to the driver trainings.

In addition, it can be concluded, that it would be beneficial to install the green driving
application to all vehicles and to instruct all drivers to drive according to the
recommendations given by the system. That would help in maximizing the benefits of the
system.

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