Large Scale Collaborative Project

7th Framework Programme

INFSO-ICT 224067

Impacts on Safety – Results and Implications

Report	Impacts on Safety – Results and Implications			
Summary	Report on results and implication of the impacts on safety			
Sub Project	SP 4		Evaluation and assessment	
Work-package	WP 4.3		Safety impact assessment	
Task	T 4.3.1 and T4.3.2		Data analysis	
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Status	Final			
Distribution	Public (PU)			
Issue date	16/01/2013	Creation date	2012-10-12	
Project start and duration	1st of June, 2008 – 54 months			

European Commission
Information Society and Media

Project co-funded by the European Commission

DG-Information Society and Media

in the 7th Framework Programme

SEVENTH FRAMEWORK PROGRAMME

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LIST OF ABBREVIATIONS

ABBREVIATION	DESCRIPTION
ADAS	Advanced Driver Assistant Systems
DFOT	Detailed Field Operational Test
FCW	Forward Collision Warning
FOT	Field Operational Test
KSI	Killed or Seriously Injured
GD	Green driving
GPS	Global Positioning System
HMI	Human Machine Interface
ICT	Information Communication Technology
ISA	Intelligent Speed Adaptation
IVIS	In-Vehicle Information System
LDW	Lane Departure Warning
NA	Navigation
ND	Nomadic Device
OD	Origin Destination
RQ	Research Question
SA	Speed alert

ABBREVIATION	DESCRIPTION
SI	Speed limit information
TI	Traffic information
UU	User uptake

REVISION CHART AND HISTORY LOG

REV	DATE	REASON
0.1	12/10/2012	First Draft
0.2	17/12/2012	Second draft with harmonisation across impact areas
0.3	20/12/2012	Third draft with comments from analysis partners
0.4	15/01/2013	Final draft after peer review
0.5	23/03/2013	Final version following review

EXECUTIVE SUMMARY

This deliverable presents the full and final analysis results in relation to the safety impact assessment. It then draws upon these results to discuss the impact that the functions provided by Nomadic Devices have upon safety.

The deliverable is structured so as to present the key results for each Research Question (RQ) and Hypothesis within the main body of the report. These main results are then restructured on a function basis in order to assess the impact of each function upon;

- Route Choice
- Distance Travelled
- Distraction
- Speed
- Lane positioning
- Braking behaviour
- Manual activity

Further supporting analysis for each RQ is provided in Annex 1. Subsequently, an evaluation is made relating any impacts observed to consequences for safety. This evaluation is made using results that refer to singular functions; results from Field operational tests (FOT) that evaluated bundles of functions are included within the results sections for each Research Question but not included within the evaluation. This is since there are no current rigorous methods accepted within the research community for dealing with bundles of functions; this is being discussed and considered within the revision of the FESTA handbook.

At a function level, the results (relating to specifically to FOTs testing single functions) are summarised as follows;

Navigation

	Questionnaire	Logged
Route Choice	Slight perceived increase in the use of rural roads	Increase in use on city / urban roads
Distance Travelled	Perception of shorter and quicker journeys with navigation function use	Logged data show significant decrease in mean distance and decrease in duration for comparable origin / destination journeys
Distraction	N/A	Increase in percentage of eyes off road time and average glance duration with navigation function use
Speed	N/A	No significant change in average speed with navigation function use. No change in speed violations.
Lane Positioning	No perceived change with navigation function use	N/A
Braking Behaviour	N/A	No significant change with navigation function use
Manual Activity	N/A	No significant change with navigation function use

Traffic Information

	Questionnaire	Logged
Route Choice	Perceived increase in use of rural roads	Increase in use of rural roads with Traffic Information function use
Distance Travelled	No perceived difference in journey length, perceived shorter journey duration with Traffic Information function use	Significantly shorter journey duration
Distraction	N/A	N/A
Speed	N/A	Increase in average speed on urban roads with Traffic Information function use
Lane Positioning	No perceived change with function use	N/A
Braking Behaviour	N/A	No significant change with Traffic Information function use
Manual Activity	N/A	No significant change with Traffic Information function use

Speed limit information / speed alert

No impacts, either perceived or logged, were found for speed limit information or speed alert.

Green Driving

	Questionnaire	Logged
Route Choice	Perceived very slight increase in use of rural roads with very slight decrease in highway use with Green Driving function use	N/A
Distance Travelled	No perceived change in journey length or duration	Increase in duration of comparable origin / destination journeys with Green Driving function use
Distraction	N/A	No significant change with Green Driving function use
Speed	N/A	No change in average speed with Green Driving function use (DFOT) No change in speed violations
Lane Positioning	No perceived change with Green Driving function use	N/A
Braking Behaviour	N/A	No significant change with Green Driving function use
Manual Activity	N/A	No significant change with Green Driving function use

Considering the implications of these results for safety, the following are inferred;

- Navigation increased both the percentage of eyes of road time and the average glance duration, intuitively this has a negative effect on safety but should be further contextualised with the road environment, the speed of travel and also judged against alternatives for navigation such as maps and printed instructions. Navigation also showed a potential to increase the use of rural roads, another negative for safety. On the other hand benefits for safety could be realised through shorter journey lengths and durations.
- Traffic information showed a slight increase in the use of rural roads in the Swedish FOT which could represent a switch to road types with a higher accident risk but also resulted in shorter journey times which reduce the exposure to accidents. There was also a slight increase in average speed on urban / city roads. These effects have apposing impacts on safety.
- Speed limit / speed alert showed no influence upon any of the research questions though according to mobility RQ11, this was the function anticipated by the participants to have the greatest safety potential.
- Green driving indicated a potential increase in exposure and accident risk due to a shift in road type and longer journeys.

Throughout the project there has been no measurable event (e.g. accidents) during the baseline and experimental conditions since these are relatively infrequent discreet events. Therefore it is impossible to quantify impacts on safety using injury as a metric since it cannot be ascertained whether injuries increased or accident numbers fell in relation to any function use. As a result the project was left to infer the impact on safety associated with the use of the functions supported by the TeleFOT devices under assessment through specific safety research questions. These research questions are in themselves generic indicators of the risk of accident and as such are not easily quantified. Therefore it is probably inappropriate to make predictions for the European dimension in relation to safety.

1. INTRODUCTION

1.1. Background

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 June 1st 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 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 5 years.

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

The analysis undertaken within the TeleFOT project aims to assess the impact of after-market nomadic devices in five distinct assessment areas; Safety, Mobility, Efficiency, Environment and User Uptake; this deliverable presents the results of the Safety analysis. In order to measure the impacts, core research questions and hypotheses were developed for each Impact Assessment area that also take into account the functionality of the devices specifically under consideration in TeleFOT. The previous deliverable D4.3.1, Safety Analysis Plan, detailed the proposed approach to be followed but did not give analysis outputs. Following this, D4.3.2, Interim Analysis Results, presented the initial results based predominantly upon pilot analyses that had been conducted. This final deliverable in the series presents the final results and together with the implications for safety associated with the use of Nomadic devices whilst driving.

In order to introduce the analyses, the concept of safety is discussed in relation to driving.

1.2. 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 applies 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.

1.2.1. Routes

Different types of roads can pose more of a risk of accidents occurring than others. The 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*'.

1.2.2. Time of Day

The UK 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 during 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.

1.2.3. Fatigue

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.

1.2.4. Distraction and Visual Behaviour

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. Jamson and 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 and Verwey (1997) also suggest 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'.*

According to Olson et al (2009), driver distraction occurs when inattention leads to a delay in recognition of information necessary to accomplish a driving task.

A nomadic device could possibly affect the visual behaviour of the driver which could in turn 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 and 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*'.

Although it is difficult to be precise regarding the number of crashes that are caused by distraction since drivers rarely admit to being distracted at the time of the accident, distraction together with inattention is thought to be a major contributor to road crashes (Stutts, 2001). The National Highway Safety Administration (NHTSA) in the US estimated that at least 25% of crashes involve some form of driver inattention or distraction whilst other studies indicate that the rate of crash-involvement amongst distracted drivers might be as high as 35-50% (Sussman et al, 1995; Wang et al, 1996; NHTSA, 1997).

One of the largest recent analyses of driver behaviour is the 100-Car Naturalistic Study (Klauer, 2006), which recorded the activities of 241 drivers over the course of 12 –13 months in order to build up a picture of how drivers behaved in cars. In this study, it was found that 78% of the crashes and 65% of near crashes had one form of inattention or distraction as a contributing factor – including inattention due to fatigue. Another part of the 100-car study, which examined film footage of drivers in their vehicles, found that all drivers partook in at least one distracting activity, and that altogether, drivers spent 14.5% of the time that the vehicle was in motion involved in a distracting activity. They engaged in a distracting activity once every 6 minutes on average. Furthermore NHTSA (2006) concluded that Short, brief glances away from the forward roadway for the purpose of scanning the driving environment are safe and actually decrease near-crash/crash risk. Even in the cases of secondary task engagement, if the task is simple and requires a single short glance the risk is elevated only slightly, if at all. However, glances totalling more than 2 seconds for any purpose increase near-crash/crash risk by at least two times that of normal, baseline driving.

In New Zealand during 2002 and 2003, driver distraction was reported in 9.5% of police reported crashes (Gordon, 2005).

According to Victor et al (2005), glance-based measures such as total glance duration, glance frequency, glance duration and total task duration are the central measures of interest in assessing the visual demand of in-vehicle information systems. A glance is described as "the transition to a given area, such as a display and one or more consecutive fixations on the display until the yes are moved to a new location". Such metrics have been shown to vary with different in-vehicle tasks. However, a consensus seems to be that glance duration should be considered in relation to the driving demand imposed by the situation, e.g. speed, and task complexity.

Nevertheless, within Europe, the role of distraction and inattention as contributory factors in road crashes is relatively under-researched. Given recent advances in vehicle technology and in-vehicle information systems, there is a requirement to understand the nature and circumstances of crashes in which distraction and inattention are thought to have been contributory factors and also to have a method for determining where distraction may have been caused by new in-vehicle systems. This is so that future in-car systems can be developed that do not distract the driver from the driving task and keep him/her attentive to the driving task to reduce the likelihood of accident involvement.

1.2.5. Speed

Aarts and 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 a device which affects proximity to the vehicle ahead can have a major effect on the vehicle occupant's safety.

In general 3 methods are used to understand the relationship between speed and accidents / casualties.

(1) Individual vehicle speed (i.e. case-control or self-report studies; driver-based): this methodology examines the relationship by determining the crash liability of individual vehicles that drive at different speeds employing self-report or case-control approaches (e.g. Fildes et al. 1991, Maycock et al. 1998, Kloeden et al. 2001). The reliability of this method largely depends on the design of the experiment and the sampling frame. It is obvious that self-report studies cannot develop a relationship between speed and fatal accidents.

(2) Intervention (before-after; road-based using time series data) studies: this methodology is based on an intervention analysis in which the change in road-level mean speeds (as a result of changing in speed limit or the implementation of speed enforcement for example) is linked with the corresponding change in accident rates with the aim of quantifying the impact of speed change on accidents (e.g. Finch et al. 1994;

Nilsson 1982, 2004). If an appropriate statistical method capable of controlling the regression-to-the-mean effect and the exposure of accidents (i.e. traffic flow/density) is employed then this methodology has potential to provide a reliable result. The drawback of this method is that an intervention such as the change in speed limit has to take place before a relationship can be developed. The reliability of the method largely depends on the spatial and temporal aspects of the intervention (i.e. the number of roads with the changes in speed limit and the duration of data collection both before and after the intervention). This is therefore a post-intervention methodology which can be employed to examine the impact of speed change on accident occurrence.

(3) Cross-sectional or panel (road-based mean speeds) studies: this methodology employs a statistical model to relate the average speed of a road segment with the accident frequency or rate of that segment. Both cross-sectional or panel datasets are employed (e.g. Lave 1985, Baruya 1998; Taylor et al. 2002, Kockelman and Ma 2007). This methodology has also been widely used in the Literature. The advantage of this method is that this is a pre-intervention approach capable of providing the elasticity of accidents with respect to mean speed. While developing a relationship between accidents and speed, this method takes into account other factors that may influence the occurrence of accidents such as traffic flow/density, road geometry and environmental conditions. One of the drawbacks of this method is the use of segment-level aggregate data (i.e. speed, traffic flow) over a period of time (e.g. a year) where the speed dispersion among the vehicles is ignored

1.2.6. Headway

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 head way 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.

Considering the Literature, it becomes apparent that there is no direct quantitative relationship between the indicators of safety and the measures (accident involvement and injury outcome) other than in the case of speed. It is possible to infer an increased or decreased risk associated with a type of behaviour or driving environment and this necessarily forms the basis of the safety impact evaluation. For the majority of the safety indicators it is not possible to quantify effects of functions in terms of a percentage increase or decrease in accidents for example, but instead conclusions will be made regarding each function's influence on the indicators of safety and then statements made as to whether the findings are detrimental or beneficial from a safety point of view.

In the case of speed, the Nilsson model provides a relationship between the increase in mean speed of the traffic flow and accident involvement / injury risk. If a function were to show a significant effect upon speed then this would need to be extrapolated to its effect on the mean flow speed across the road network, or sections of that network, and the resulting change in accident rate could be calculated.

2. SAFETY RESEARCH QUESTIONS

Based upon the knowledge demonstrated in section 1.2 together with an assessment of the feasibility of collecting data to support analysis, a number of safety research questions and hypotheses were developed using a ‘top-down-bottom-up methodology (reported in TeleFOT Deliverables D2.2.1 and D4.3.1 and also in Franzen et al, 2012) in relation to the use of nomadic information systems in passenger cars. These were as follows;

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 addition the deliverable also draws upon the results of the Mobility RQ11 which considers how the functions effect the participant's perception of safety. 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. The objective of this deliverable is to provide the key results for each Research Question and Hypothesis along with the impact on safety of the Functions assessed. This provides the reader with a clear summary of the major findings in a succinct manner. Further supporting analysis for each RQ is provided in Annex 1. In addition to the RQs noted above, the safety impact assessment also draws upon relevant information provided by the other assessment domains within TeleFOT. It should be noted that this deliverable does not document the way in which the data were collected or describe test sites and FOTs since this is covered in deliverables relating to SP3 (D3.5.1 and D3.6.1) Where appropriate it does however describe post processing that has been undertaken aside from the general database development and that is specific to the research question.

3. METHOD

3.1. General Method

In order to produce consistent and coherent analyses, a template has been devised which provides the structure for reporting each hypothesis test undertaken. This covers the following sections:

- Hypothesis analysed
- Data used
- Reasons for exclusion of data at FOT level
- Anticipated effect of function to be tested
- Anticipated influence of combinations of functions
- Data selection, filtering and post processing for analysis
- Statistical testing applied
- Results
- Contextual discussion
- Caveats
- Conclusions from analysis

Wherever possible, these sections have been completed by the researcher undertaking the analysis for each hypothesis. Where there is insufficient evidence to form opinions, the section is left blank.

Research questions 1 and 2 concerning exposure to the road, and where LFOT data has been used extensively, have been further analysed where appropriate to consider the influence of other factors such as driver age and gender along with the time of day that travel takes place.

Results are summarised in section 4 according to function. For clarity within the results only those pertaining to testing *SINGLE FUNCTIONs* are considered when making conclusions but all results available are presented. This is because this reduces the complications of disaggregating the effects of multiple functions. It is also the case that the questionnaire data is analysed according to single function perceptions and hence correlation and comparison can be drawn between the logged and the questionnaire data if both conclude from single function results. In addition there is as yet no clear and common methodological agreement within the research community for handling this issue; FOTNET is currently developing guidelines for future FOTs and Naturalistic Driving Studies.

As mentioned previously, the report is structured so as to provide key results whilst the full supporting analysis is presented in the later Annex I.

3.2. Data sources

The analysis undertaken for this impact assessment has used logged data and questionnaire data from the LFOTs and logged data from the DFOTs.

3.2.1. LFOT

In the large scale FOTs, all test vehicles were equipped with Global positioning system (GPS) loggers that collected at least the coordinates, heading and speed. Most of them also collected altitude and number of satellites visible. Some FOTs collected nomadic device and navigator usage logs such as function activation and traffic information messages received. However, this information was not collected for all FOTs. (Koskinen 2012)

Raw data were logged as gigabytes per month and processed before analysis. This gave the analysts similar summary data sets for each logger and FOT. First, the data format was harmonised and the driving diaries were then extracted. Each leg in the diary contained multiple derived variables describing the leg that might indicate driving style. Legs with common origins and destinations were identified and many analyses were based on comparable journeys. (Koskinen 2012)

Logged kilometres of participants whose logged data contributed to the analysis varied per FOT from 193 000 km to 3 300 000 km and driving hours from 3 800 hours to over 72 000 hours (Table 1) The largest amount of data was from the Italian LFOT with 150 participants and the smallest amount of data was from the UK LFOT with 60 participants. It should be noted that the number of participants or logged kilometres used in the analysis may be smaller than the total number of participants or total kilometres due to early drop-outs etc.

FOT	Function(s)	Number of participants	Total driving km	Total driving hours
Finland LFOT	GD, SI/SA, TI	125	334 013	7 489
Greece LFOT	NA, SI, SA, TI	148	805 456	18 842
Italy LFOT	NA, SI/SA	150	3 325 630	72 312
Spain LFOT1	NA, SI/SA	120	871 508	19 516
Sweden LFOT2	GD, NA, TI	87	622 244	12 865
UK LFOT	NA, SI/SA	60	192 740	3 785

Table 1; Number of participants whose logged data contributed to the analysis, total driving kilometres and hours in different FOTs

Questionnaire data was collected from a background questionnaire and user uptake questionnaires. User uptake questionnaires were prepared per function. The participants completed separate questionnaires for each function they tested at the start of the trial (pre-questionnaire), once or twice during the treatment phase depending on its length (during-questionnaires), and once at the end of the trial (post-questionnaire). The number of participants who had completed user uptake questionnaires is shown in Table 2.

It should be noted that further selection of data were undertaken dependent upon the needs of each RQ. The specific data used for each RQ is tabulated in the relevant sections.

FOT	Function(s)	Number of participants who completed the questionnaire			
		Pre	During1	During2	Post
Finland LFOT	GD, SI/SA, TI	GD: 119 TI: 119 SI/SA: 111	59 76 21	43 52 18	56 68 24
Greece LFOT1-4	NA, SI, SA, TI	NA:148 SI:134 SA: 136 TI: 134	141 126 124 127	– – – –	137 115 115 118
Italy LFOT	NA, SI/SA	NA: 137 SI/SA: 136	117 116	– –	113 112
Spain LFOT1	NA, SI/SA	NA: 118 SI/SA: 118	93 92	96 96	96 94
Sweden LFOT2	GD, NA, TI	GD: 91 NA: 94 TI: 94	83 82 82	74 77 75	63 68 61
UK LFOT	NA, SI/SA	NA: 77 SI/SA: 79	49 48	45 39	42 40

Table 2 Number of participants who completed the user uptake questionnaires in each FOT

3.2.2. DFOTs

Since the DFOT design was very specific to the RQ that used the data, a description is included in each relevant analysis section.

4. ANALYSES

In this section the analysis results for each of the safety research questions are presented. In addition reference is also made to the Mobility research question relating to the participants' perception of safety (MRQ11).

4.1. SRQ 1 - Is the route affected? (Where travel takes place)

There are 3 hypotheses associated with this research question

- 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 (commuting journeys).
- H1.2 People choose different routes (based on road type) when the device is used compared to when it is not (commuting journeys)
- H1.3 There is a change in the proportion of urban/rural driving when the device is used compared to when it is not (commuting journeys)

The data available allowed for analysis to be undertaken relating to H1.1 and H1.2 but not H1.3. 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

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

The results presented here are taken from the mobility impact assessment and so do not fit directly into the template used in this deliverable.

<u>Data used</u>

FOT	Function(s)	Number of participants	Total driving km	Total driving hours
Finland, LFOT	GD, SI/SA, TI	125	334 013	7 489
Italy, LFOT	NA, SI/SA	150	3 325 630	72 312
Spain, Valladolid LFOT	NA, SI/SA	120	871 508	19 516

FOT	Function(s)	Number of participants	Total driving km	Total driving hours
Sweden LFOT2	GD, NA, TI	87	622 244	12 865
Sweden, LFOT4	TI	260	465 075	7 944
UK, LFOT	NA, SI/SA	60	192 740	3 785
Spain, LFOT2	GD, TI	132	1 446 316	58 025

Table 3; Data used for Hypothesis H1.1

Reasons for exclusion of data at FOT level

All test sites listed above were included in the analysis. No exclusions were made.

Data selection, filtering and post processing for analysis

This research question was investigated by assessing whether there was a change in the proportion of road types driven on when the device was available compared to when it was not. For logged data, the classification of road types used followed the system Navteq uses and map matching was done with software developed by Navteq. Consequently, road types were defined as shown in Table 4. It should be noted that more types existed in the data but special types that are very seldom used were not included in this assessment.

Road type	Description
Type 0	High speed and traffic volume between major metropolitan areas, controlled access roads
Type 2	High traffic volume, high speed traffic between metropolitan areas and major cities
Type 3	High volume traffic at a lower level of mobility than Type 2
Type 5	High volume traffic at moderate speed between additional neighbourhoods/cities
Type 6	Slow speed within cities/neighbourhoods
Type 9	Pedestrian zone
Type 11	Point of interest access
Type 12	Private road
Type 13	Unpaved road

Table 4; Road type descriptions by Navteq

As is apparent from Table 4, Navteq classifies roads according to how fast cars travel on them, rather than common classifications such as highway, rural road, city street etc. For simplicity “Type 0” can be translated to “Highways/motorways”, “Type 2–3” to “Interurban or rural roads”, and “Type 5–6” to “Urban roads or city streets”. The rest of the road types are special cases typically within cities or in rural areas. The common classifications were used in the questionnaires.

All test sites were included in the analysis except the Greek LFOT. The analysis was based on frequently made journeys. In practice, same origin-destination (OD) pairs were searched in baseline and treatment conditions for each participant. In the logged data, the radius of 100 metres was used to determine origins and destinations. All origin destination pairs that a single test participant had had at least once during the baseline phase and at least once during the treatment phase were included in the analysis. One origin-destination pair contributed one sample per participant.

Logged data analysis covered only the possibility to use the function. Logging did not include actual use of the system, thus the impacts of actual use could not be analysed.

<u>Statistical testing applied</u>

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

H0: The function has no influence on route choice

H1: The function has an influence on route choice

Also tested was the possible effect on variance of road type choice due to having access to the TeleFOT functions. For this test, logged data were selected from each LFOT. In order to analyse variance, there must be a relatively high number of journeys between a certain origin-destination pair. Therefore the sample was selected based on the following criterion: at least 30 journeys with the same origin and destination in the data (at least four in both baseline and treatment phases). Changes in variation were quantified by performing a chi-squared test of independence, before and after installation, on clustered road type profiles. Clusters of road type profiles were computed using the k-means algorithm with k = 5 as number of clusters.

Results

	Finland LFOT	Italy LFOT	Spain LFOT1	Sweden LFOT2	UK LFOT
Functions	GD, SI/SA, TI	NA, SI/SA	NA, SI/SA	NA, TI, GD	NA, SI/SA
N	277	22	1212	1632	358
Highways/motorways (Type 0)	12.3/13.9	0.0/0.0	3.6/3.4	10.3/10.3	7.8/7.7
Interurban roads (Type 2)	19.0/18.5	12.0/12.4	31.8/28.9	13.6/13.4	11.2/11.8
Rural roads (Type 3)	18.9/18.4	27.3/31.5	18.2/16.9	21.6/21.8	27.8/27.8
Urban roads (Type 5)	27.5/27.7	41.8/40.9	14.9/14.3	21.0/21.0	23.0/22.2
Urban streets (Type 6)	16.5/16.4	18.7/14.9	28.7/30.6	31.7/31.6	27.6/27.7
Pedestrian zone (Type 9)	0.1/0.2	n/a	0.3/0.3	n/a	n/a
Point of interest access (Type 11)	0.1/0.1	n/a	0.1/0.0	n/a	n/a
Private roads (Type 12)	0.0/0.0	n/a	0.1/0.2	n/a	n/a
Unpaved roads (Type 13)	5.4/4.7	n/a	1.9/3.1	n/a	n/a

n/a = not available; Type 9–13 contributed together 0.2–2.8% of road types used for the FOTs for which they the proportions were not calculated

Table 5; Mean use of different road types during baseline and treatment phases (baseline/treatment, %), significant differences in bold ($p < 0.10$)

Only a very small number of significant changes in route choice were found in two of the five datasets analysed. Almost all non-significant cases were nowhere near the significance level (0.1). Moreover, the few truly significant changes were weak due to very few points in the baseline period. Thus, no convincing results were found in any of the datasets that indicate an effect of the installed functions. With the low amount of "common trips" found in the material, no division of sub-groups was undertaken in the logged data. The conclusion of the variance test was therefore that there were no detectable differences in variance between baseline and treatment conditions for any of the LFOTs. However, the low number of commonly used origin-destination pairs logged made the analysis difficult.

Dataset	Number of legs in original data set	Number of legs with unique combination of logger and OD pair	Filtered legs with N ≥ 30	Number of legs with significant route change in filtered set
Finland LFOT	11 686	6 642	7	0
Italy LFOT	4 568	3 551	1	0
Spain LFOT1	37 106	27 118	20	2 (10%)
Sweden LFOT2	37 620	18 435	59	1 (2%)
UK LFOT	6 994	4 601	6	0

Table 6; Number of legs with significant change in route choice

<u>Caveats</u>

Logged data analysis covered only the possibility to use the function. Logging did not include the actual use of system, thus, the impacts of actual use could not be analysed.

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

Three different questions in the User Uptake questionnaires were answered post trials that regarded route choice:

> Do you find that any of the following has changed due to your access to the FUNCTION? [The distance you cover to reach your destinations]
>
> Do you find that any of the following has changed due to your access to the FUNCTION? [Your use of highways/motorways]

Do you find that any of the following has changed due to your access to the FUNCTION? [Your use of rural roads]

Data Used

FOT	Function(s)	Number of participants	Total driving km	Total driving hours
Finland, LFOT	GD, SI/SA, TI	125	334 013	7 489
Italy, LFOT	NA, SI/SA	150	3 325 630	72 312
Spain, Valladolid LFOT	NA, SI/SA	120	871 508	19 516
Sweden LFOT2	GD, NA, TI	87	622 244	12 865
Sweden, LFOT4	TI	260	465 075	7 944
UK, LFOT	NA, SI/SA	60	192 740	3 785
Spain, LFOT2	GD, TI	132	1 446 316	58 025

Table 7; Data used for Hypothesis H1.2

Data selection, filtering and post processing for analysis

For the questionnaire data no filtering was done.

Statistical testing applied

N/A using post questionnaire distributions

Results

FOT	Function	Reported change
Greece, LFOT; Italy, LFOT; Sweden, LFOT2; UK, LFOT; Spain, LFOT1	NA	Slight increase in use of rural roads, No effect on highway use. Consistent result through FOTs
Finland, LFOT; Greece, LFOT; Italy, LFOT; Sweden, LFOT2; Sweden, LFOT1; UK LFOT; Spain LFOT1	SP	No effect on road type choice. Consistent results thorough FOTs
Finland, LFOT; Greece LFOT; Sweden, LFOT2; Sweden, LFOT4	TI	No effect on highway use, Slight increase of Rural road use, FIFOT reported no effects
Finland, LFOT; Sweden, LFOT2; Sweden, LFOT1	GD	Very slight decrease of highway use and increase of rural road use. (about 5% of participants reported a slight increase or decrease) Consistent results thorough FOTs

Table 8; Summary of results for Hypothesis H1.2

For most of the functions tested, the questionnaire answers related to route choice were there was no change. The reported change in the use of highways (Figure 1) or rural roads (Figure 2) shows that a great majority reported “no change”. For highway use over 90% reported “no change”, and the few who reported a change did so in both directions. For the use of rural roads, the results showed some change as a slight increase was reported by 10.4% of the participants due to navigation (tendency towards smaller roads is in line with the logged data result above), and almost as many (7.8%) due to traffic information. This is in some sense an intuitive result; with navigation a driver is often routed to smaller roads while road signs usually route a driver through the main road network. Avoiding traffic jams will also route a driver on smaller roads away from congested highways. The green driving result of slight decrease of highway use contradicts the above Finnish LFOT result based on logged data.

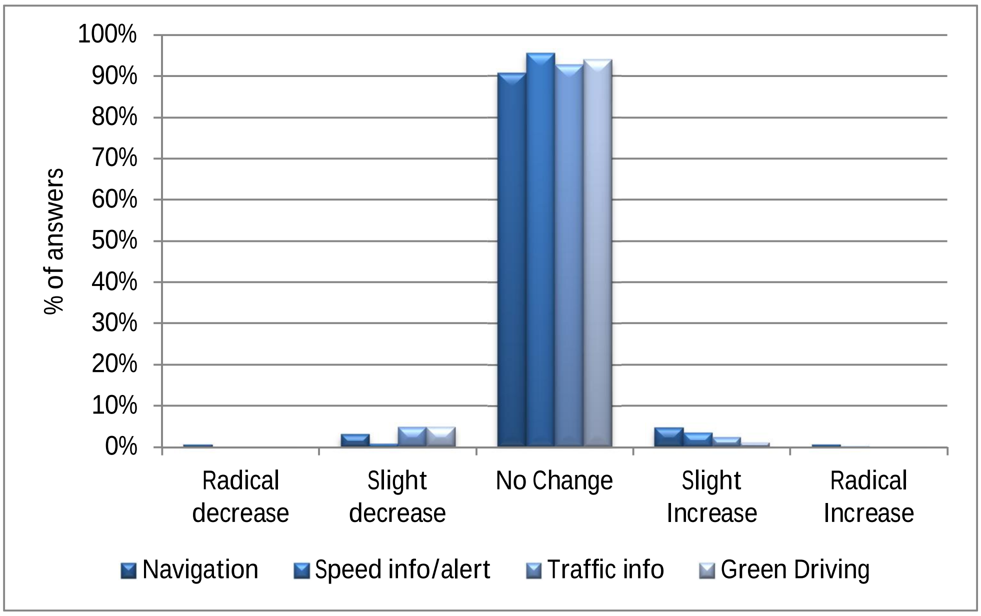

Figure 1; Change in use of highways due to access to TeleFOT function, average over all LFOTs, post questionnaire

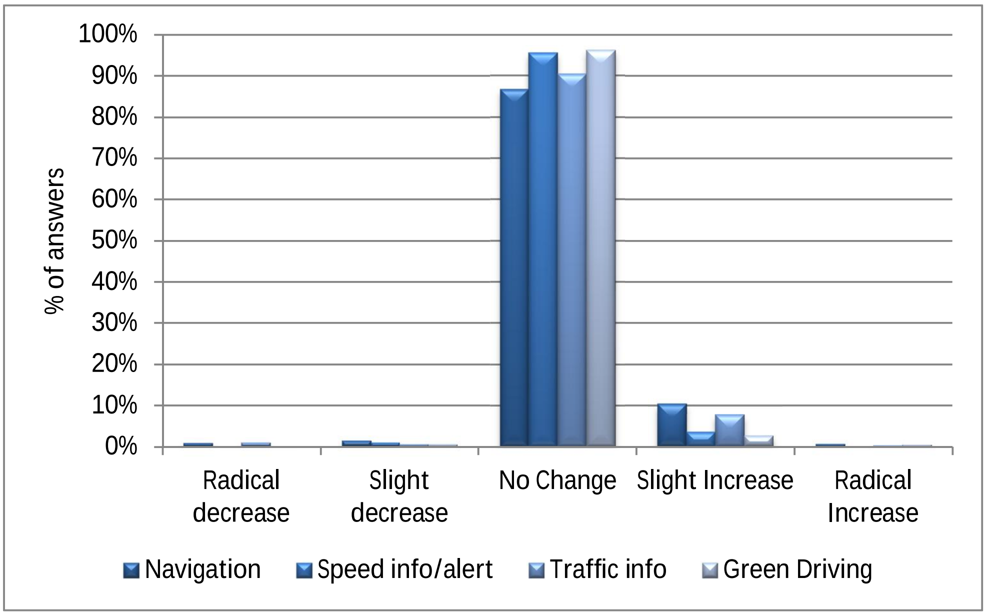

Figure 2; Change in use of rural roads due to access to TeleFOT function, average over all LFOTs, post questionnaire

Conclusions from analysis

The Spanish LFOT1 stands out with significant changes in the proportion of road types used (a shift from higher class roads to lower class roads, e.g. urban streets and unpaved roads), and significantly increased variance in used road types for two of 20 of the tested origin-destination pairs. One explanation is that navigation allowed the participants to pass through the city centre rather than bypassing it on larger roads (minimised route length) or guided them via shortcuts using unpaved roads in rural areas. Eight per cent of participants, however, reported an increased used of highways and 6% reported an increased use of rural roads. On the other hand, logged data results indicated shorter distances and durations with navigation, which would be in line with the theory of finding a shorter route through the city centre or in rural areas. For the two other test sites using the same device (Italy and UK LFOTs), the numbers went in the opposite direction (although not statistically significantly due to much lower numbers of pairs). However, the logged data showed very small differences in distance or duration for these FOTs.

For the Finnish LFOT1 (GD, SI/SA + TI), there was a shift from interurban and rural roads to highways. One explanation could be that green driving support has made highways more attractive than smaller roads with potential stop and go traffic. The Swedish LFOT2 used a TMC-based traffic information service that was reported by the participants to be unreliable, sluggish, and showing only some incidents of traffic disturbance; it was therefore reported as little used. The findings from the logged data were, however, contradicted by the questionnaire answers that stated that traffic information increased the use of rural roads somewhat. This might, of course, be another effect of the different road type definitions used in the different data sources.

Although there is no change in road type distribution, impacts on distance also indicate use of new routes. The same applies to duration, as none of the functions have an impact on the traffic situation — if a driver completes journeys faster than in the baseline condition, it is likely that he/she has found a better route. Here a slight decrease in distance was reported by many participants. It may be interpreted as the participants having found a slightly shorter route for many trips, but a more conservative interpretation is that they found shorter routes for some trips.

The main conclusions from the analyses on route choice are that the functions tested in TeleFOT may change peoples' route choices. Navigation stands out as the function that seems to have the largest impact, followed by traffic information. Also green driving support indicates that participants have changed their route preferences.

4.2. SRQ 2 - Is the amount of time on that 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 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

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

Data used

FOT	Function / s	Data Type	Number of participants			
			Pre	During1	During2	Post
Finland	GD, SI/SA, TI	Questionnaire	GD: 119 TI: 119 SI/SA: 111	59 76 21	43 52 18	56 68 24
Greece, LFOT1-4	NA, SI, SA, TI	Questionnaire	NA:148 SI:134 SA: 136 TI: 134	141 126 124 127	– – – –	137 115 115 118
Italy	NA, SI/SA	Questionnaire	NA: 137 SI/SA: 136	117 116	– –	113 112

Spain, Valladolid	NA, SI/SA	Questionnaire	NA: 118 SI/SA: 118	93 92	96 96	96 94
Sweden LFOT2	GD, NA, TI	Questionnaire	GD: 91 NA: 94 TI: 94	83 82 82	74 77 75	63 68 61
Sweden, LFOT4	TI	Questionnaire	TI: 231	65	–	43
UK, LFOT	NA, SI/SA	Questionnaire	NA: 77 SI/SA: 79	49 48	45 39	42 40

Table 9; Data used for Hypothesis H2.1

<u>Reasons for exclusion of data at FOT level</u>

All test sites where questionnaires have been completed were included in the analysis.

<u>Anticipated effect of function to be tested</u>

NAV, GD, TI are likely to affect decisions of whether to travel somewhere or not, and thereby number of journeys. SA, SI are anticipated to only have indirect effect via travel comfort, likely very low.

<u>Data selection, filtering and post processing for analysis</u>

The analysis was based on the answers in questionnaires (pre, during and post) to question “Do you think that any of the following will change / have changed as a result of your access to FUNCTION? [The number of journeys you make by car; the number of journeys you make by public transport]”.

Those participants were selected who had filled all the questionnaires.

<u>Statistical testing applied</u>

The Friedman Test was used to test for differences between questionnaires. If a difference was found, the Wilcoxon Test with Bonferroni adjustment was used to analyse between which questionnaires the difference existed.

Hypotheses:

H0: There is no change in the number of journeys over time

H1: There is a change in the number of journeys over time

Results

FOT	Treatment	Main results
All	Green Driving	No perceived change in number of journeys
All	SI/SA	No perceived change in number of journeys
All	TI	No perceived change in number of journeys
All	Navigation	No perceived change in number of journeys

Table 10; Summary of results for hypothesis H2.1

Conclusions from analysis

Questionnaire data was used to assess the hypothesis "Participants report a change in the number of journeys undertaken because they have the device". Most participants assessed not to have an impact on number of car or public transport journeys due to having access to any of the functions. More participants expected functions to have an impact on number of car journeys than on number of public transport journeys. Participants had least expectations towards speed information/alert. For all test sites and functions, the proportion of answer "no change" increased from pre-test to post-test (from 81–100% to 86–100%). Participants of Swedish LFOT2 and LFOT4 had highest expectations of an impact in number of journeys for Green driving and Traffic information (7–19% of participants, pre-questionnaires). Also Greek LFOT1 expectations for Navigation impact were high (9-17% of participants, pre-questionnaires). Those who expected or assessed to have experienced a change in number of car or public transport journeys assessed the use of functions more often to slightly increase their number of car journeys and slightly decrease their number of public transport journeys than vice versa.

Correlation to background variables

Correlations to background variables were not calculated, because there were not enough participants who assessed there to be a change in number of journeys during trial.

Correlation to Travel diary data

Travel diary data was in concordance with questionnaire data only for the Finnish LFOT with Green driving and Speed information. For other functions and LFOTs the results were not consistent.

More specific correlations to travel diary data were not calculated, because there were not enough participants who assessed there to be change in number of journeys in the post-questionnaire, nor significant differences between travel diaries.

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

Data used

FOT	Function/s	Data Type	Number of participants	Total driving km	Total driving hours
Finland, LFOT	GD, SI/SA, TI	Logged	125	334, 013	7,489
Italy, LFOT	NA, SI/SA	Logged	150	3, 325, 630	72, 312
Spain, Valladolid LFOT	NA, SI/SA	Logged	120	871, 508	19, 516
Spain, Madrid LFOT	GD, TI	Logged	132	1, 446, 316	58, 025
Sweden LFOT2	GD, NA, TI	Logged	87	622, 244	12, 865
Sweden, LFOT4	TI	Logged	260	465, 075	7, 944
UK, LFOT	NA, SI/SA	Logged	60	192, 740	3, 785
Greece, LFOT1-4	NA, SI, SA, TI	Logged	148	805, 456	18 ,842

Table 11; Data used for hypothesis H2.2

Reasons for exclusion of data at FOT level

All of the FOTS listed above were included in the analysis.

The analysis was based on frequently made journeys. In practice, same origin destination pairs were searched in baseline and treatment conditions for each participant. The radius of 100 metres was used to determine the locations where the vehicles had stopped.

Anticipated effect of function to be tested

NAV, GD, TI are likely to affect travel decisions of personal journeys including the destinations and routes, and thereby length of journeys. SA, SI are estimated to have only an indirect effect via travel comfort, likely very low.

Data selection, filtering and post processing for analysis

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

Mean distance driven between comparable OD pairs was calculated for both periods and compared.

Analysis covers only the possibility to use the function. Logging did not include the actual use of system, thus, the impacts of actual use could not be analysed based on logger data.

Statistical testing applied

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

Hypotheses:

H0: The function has no influence on the distance

H1: The function has an influence on the distance

Results

A summary of the results is presented in the following table. The full analysis is provided in Annex I.

FOT	Baseline	Treatment	Main results
Finland LFOT	TI	TI	No significant change in mean distance
Finland LFOT	TI	TI, GD, SI/SA	No significant change in mean distance
Finland LFOT	TI, SI/SA	TI	No significant change in mean distance
Finland LFOT	TI, SI/SA	TI,GD	Significant increase in mean distance
Finland LFOT	TI, SI/SA	TI, SI/SA, GD	No significant change in mean distance
Finland LFOT	TI, GD	TI, GD, SI/SA	No significant change in mean distance
Valladolid LFOT	-	NA, SI/SA	Significant decrease in mean distance
Spain Madrid LFOT	-	GD	No significant change in mean distance
Spain Madrid LFOT	-	TI	No significant change in mean distance
UK LFOT	-	NA, SI/SA	No significant change in mean distance
Italy LFOT	-	NA, SI/SA	No significant change in mean distance
Sweden LFOT4	-	TI	No significant change in mean distance
Sweden LFOT2	-	GD, NA, TI	No significant change in mean distance
Greece LFOT1	-	NA	No significant change in mean distance
Greece LFOT2	NA	NA, SI	No significant change in mean distance
Greece LFOT3	NA	NA, TI	No significant change in mean distance
Greece LFOT4	NA	NA, SA	No significant change in mean distance

Table 12; Summary of results for Hypothesis H2.2

Contextual discussion

The analysis showed that there were no statistically significant differences between the group that had a change in distance during trial and those who did not.

Conclusions from analysis

Logged data was used to assess the hypothesis “There is a change in the distance travelled between comparable origins and destinations”. The only statistically significant differences were that the distance was for function pair traffic information and green driving 9.6% longer than for traffic information and speed information/alert in Finnish LFOT and 2.5% shorter with the bundle “navigation and speed information/alert” than without any functions in Spanish Valladolid LFOT.

The green driving application (when traffic information and speed information/alert were the baseline, Finnish LFOT) showed also an increase in distance while the bundle “green driving and speed information/alert” (traffic information as baseline, Finnish LFOT) showed a decrease. Those results were not statistically significant. Nevertheless, this may indicate that green driving application affects the distance by increasing it while speed information/alert tend to decrease it.

UK LFOT and Italy LFOT with the same bundle “navigation and speed information/alert” result were contradictory to Valladolid result. However, UK and Italy results were not statistically significant.

The same changes than in logger data could be seen in questionnaire data with Traffic information, and in Greek and Spanish Valladolid LFOTs with Speed information and Navigation. Spanish Valladolid LFOT could be studied also on participant group level (if those who had a decrease in questionnaire also had a decrease in logger data), and the changes were in the same direction only for Navigation.

There were no statistically significant differences in background variable distributions between the group that had a change in distance during trial and those who did not.

For rush hour, daytime and night time journeys the difference between origin-destination pairs was smaller than for all journeys in most LFOTs. There was one LFOT (Spanish Valladolid) where there was a statistically significant difference in all journeys but not in rush hour or daytime journeys. For Swedish LFOT there was a statistically significant difference in daytime journeys but not in all journeys. For night time journeys, there were three LFOTs (Italian LFOT, Finnish LFOT with Green driving and Greek LFOT1 with Navigation) that had a statistically significant difference between baseline and treatment, but the difference could not be seen in all journeys. On the contrary, in Finnish LFOT with Green driving and SI/SA there was a difference only for all journeys.

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

Data used

FOT	Function / s	Data Type	Number of participants			
			Pre	During1	During2	Post
Finland, LFOT	GD, SI/SA, TI	Questionnaire	GD: 119 TI: 119 SI/SA: 111	59 76 21	43 52 18	56 68 24
Greece, LFOT1-4	NA, SI, SA, TI	Questionnaire	NA:148 SI:134 SA: 136 TI: 134	141 126 124 127	– – – –	137 115 115 118
Italy, LFOT	NA, SI/SA	Questionnaire	NA: 137 SI/SA: 136	117 116	– –	113 112
Spain, Valladolid LFOT	NA, SI/SA	Questionnaire	NA: 118 SI/SA: 118	93 92	96 96	96 94
Sweden LFOT2	GD, NA, TI	Questionnaire	GD: 91 NA: 94 TI: 94	83 82 82	74 77 75	63 68 61
Sweden, LFOT4	TI	Questionnaire	TI: 231	65	–	43
UK, LFOT	NA, SI/SA	Questionnaire	NA: 77 SI/SA: 79	49 48	45 39	42 40

Table 13; Data used for Hypothesis H2.3

Reasons for exclusion of data at FOT level

All test sites where questionnaires have been filled were included in the analysis.

Anticipated effect of function to be tested

NAV, GD, TI are likely to affect travel decisions of personal journeys including the destinations and routes, and thereby length of journeys. SA, SI effect is only indirect via travel comfort and likely very low. Total journey length is a key indicator for mobility, and should be included in the analyses.

Data selection, filtering and post processing for analysis

The analysis was based on the answers in questionnaires (pre, during and post) to question “Do you think that any of the following will change / have changed as a result of your access to FUNCTION? [The distance you cover to reach your destination]”.

Those participants were selected who had filled all the questionnaires analysed together.

Statistical testing applied

The Friedman Test was used to test for differences between questionnaires. If a difference was found, the Wilcoxon Test with Bonferroni adjustment was used to analyse between which questionnaires the difference existed.

Hypotheses:

H0: There is no change in distance travelled

H1: There is a change in distance travelled

Results

FOT	Treatment	Main results
All	Green Driving	No perceived change in distance travelled
All	SI/SA	No perceived change in distance travelled
All	TI	No perceived change in distance travelled
All	Navigation	Some perception distance travelled is decreased

Table 14; Summary of results for H2.3

Conclusions from analysis

Questionnaire data was used to assess the hypothesis "Participants report a change in the distance travelled between comparable origins and destinations". Most participants assessed not to have experienced a change in the distance travelled between comparable origins and destinations due to having access to any of the functions. However, for the navigation most participants expected an impact in distance in the pre-questionnaire. For all test sites and functions, the proportion of answer "no change" increased from pre-test to post-test (from 26–92% to 58–98%). Those who expected or assessed to have experienced a change in distance driven assessed a slight increase more often than a decrease for green driving application for most test sites. For other functions a slight decrease was chosen more often than an increase.

The same changes than in logger data could be seen in questionnaire data with Traffic information, and in Greek and Spanish Valladolid LFOTs with Speed information and Navigation. Spanish Valladolid LFOT could be studied also on participant group level (if those who had a decrease in questionnaire also had a decrease in logger data), and the changes were in the same direction only for Navigation.

For most LFOTs and functions there were no significant differences in change in distance when it was compared to background variables. There was some impact of age and transport mode for Swedish LFOT2 and Spanish Valladolid LFOT.

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

Data used

FOT	Function / s	Data Type	Number of participants	Total driving km	Total driving hours/minutes
Finland, LFOT	GD, SI/SA, TI	Logged	125	334 013	7 489
Italy, LFOT	NA, SI/SA	Logged	150	3 325 630	72312
Spain, Valladolid LFOT	NA, SI/SA	Logged	120	871 508	19 516
Sweden LFOT2	GD, NA, TI	Logged	87	622 244	12 865

FOT	Function / s	Data Type	Number of participants	Total driving km	Total driving hours/minutes
Sweden, LFOT4	TI	Logged	260	465 075	7 944
UK, LFOT	NA, SI/SA	Logged	60	192 740	3 785
Greece, LFOT1-4	NA, SI, SA, TI	Logged	148	805 456	18 842

Table 15; Data used for Hypothesis H2.4

<u>Reasons for exclusion of data at FOT level</u>

All test sites were included in the analysis.

The analysis was based frequently made journeys. In practice, same origin destination pairs were searched in baseline and treatment conditions for each participant. The radius of 100 metres was used to determine the locations where the vehicles had stopped.

<u>Anticipated effect of function to be tested</u>

NAV, GD, TI, SA, SI are likely to affect travel decisions of personal journeys, and thereby duration of journeys.

<u>Data selection, filtering and post processing for analysis</u>

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

Mean duration was calculated for both periods for each origin destination pair, and compared.

Analysis covers only the possibility to use the function. Logging did not include the actual use of system, thus, the impacts of actual use could not be analysed based on logger data.

Statistical testing applied

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

Hypotheses:

H0: The function has no influence on the duration

H1: The function has an influence on the duration

Results

FOT	Baseline	Treatment	Main results
Finland LFOT	TI	TI	No significant influence on comparable journey duration
Finland LFOT	TI	TI, GD, SI / SA	No significant influence on comparable journey duration
Finland LFOT	TI, SI / SA	TI	No significant influence on comparable journey duration
Finland LFOT	TI, SI / SA	TI, GD	Significant influence on comparable journey duration (longer)
Finland LFOT	TI, SI/SA	TI, SI/SA, GD	Significant influence on comparable journey duration (longer)
Finland LFOT	TI, GD	TI, GD, SI / SA	No significant influence on comparable journey duration
Spain Valladolid LFOT	–	NA, SI / SA	Significant influence on comparable journey duration (shorter)
UK LFOT	–	NA, SI / SA	No significant influence on comparable journey duration
Italy LFOT	–	NA,SI / SA	No significant influence on comparable journey duration
Sweden LFOT4	–	TI	No significant influence on comparable journey duration
Sweden LFOT2	–	GD, NA, TI	Significant influence on comparable journey duration (shorter)
Greece LFOT1	–	NA	No significant influence on comparable journey duration
Greece LFOT2	NA	NA, SI	No significant influence on comparable journey duration
Greece LFOT3	NA	NA, TI	Significant influence on comparable journey duration (shorter)
Greece LFOT4	NA	NA, SA	No significant influence on comparable journey duration

Table 16; Summary of results for Hypothesis H2.4

Conclusions from analysis

Logged data was used to assess the hypothesis “There is a change in the duration of journeys travelled between comparable origins and destinations”. The statistically significant differences were that the duration was 13.1% longer with green driving than without it in Finnish LFOT for those participants who had traffic information and speed information/alert as baseline functions, 18% longer with green driving compared to speed information/alert, 8.8% shorter with navigation and speed information/alert in Valladolid LFOT, 10 % shorter with green driving, traffic information and navigation in Swedish LFOT2, when compared to baseline without any functions, and 9.7% shorter with navigation and traffic information when compared to only navigation in Greek LFOT3.

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

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

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

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

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

Data used

FOT	Function / s	Data Type	Number of participants			
			Pre	During1	During2	Post
Finland, LFOT	GD, SI/SA, TI	Questionnaire	GD: 119 TI: 119 SI/SA: 111	59 76 21	43 52 18	56 68 24
Greece, LFOT1-4	NA, SI, SA, TI	Questionnaire	NA:148 SI:134 SA: 136 TI: 134	141 126 124 127	– – – –	137 115 115 118
Italy, LFOT	NA, SI/SA	Questionnaire	NA: 137 SI/SA: 136	117 116	– –	113 112
Spain, Valladolid LFOT	NA, SI/SA	Questionnaire	NA: 118 SI/SA: 118	93 92	96 96	96 94
Sweden LFOT2	GD, NA, TI	Questionnaire	GD: 91 NA: 94 TI: 94	83 82 82	74 77 75	63 68 61
Sweden, LFOT4	TI	Questionnaire	TI: 231	65	–	43
UK, LFOT	NA, SI/SA	Questionnaire	NA: 77 SI/SA: 79	49 48	45 39	42 40

Table 17; Data used for Hypothesis H2.5

Reasons for exclusion of data at FOT level

All test sites where questionnaires have been filled were included in the analysis.

Anticipated effect of function to be tested

NAV, GD, TI, SA, SI are all likely to affect travel decisions of personal journeys, and thereby duration of journeys.

Data selection, filtering and post processing for analysis

The analysis was based on the answers in questionnaires (pre, during and post) to question “Do you think that any of the following will change / have changed as a result of your access to FUNCTION? [The time it takes you to reach your destination]”.

Those participants were selected who had filled all the questionnaires analysed together.

Statistical testing applied

The Friedman Test was used to test for differences between questionnaires. If a difference was found, the Wilcoxon Test with Bonferroni adjustment was used to analyse between which questionnaires the difference existed.

Hypotheses:

H0: There is no change in duration of journey

H1: There is a change in duration of journey

Results

FOT	Treatment	Main results
All	Green Driving	No perceived change in journey duration
All	SI/SA	No perceived change in journey duration
All	TI	Perceived change in journey duration (shorter)
All	Navigation	Perceived change in journey duration (shorter)

Table 18; Summary of results for Hypothesis H2.5

Conclusions from analysis

Questionnaire data was used to assess the hypothesis “Participants report a change in the duration of journeys travelled between comparable origins and destinations”.

Most participants assessed not to have experienced a change in the duration of journey between comparable origins and destinations due to having access to any of the functions. However, for the navigation most participants expected a slight decrease in duration in the pre-questionnaire. The same expectation existed also for green driving in Swedish LFOT2 as well as traffic information in Swedish LFOT2 and LFOT4, and Greek LFOT3.

For all test sites and functions, the proportion of answer “no change” increased from pre-test to post-test (from 14–72% to 39–87%). Those who expected or assessed to have experienced a change in duration assessed a slight increase for speed information/alert and a slight decrease for traffic information and navigation. For green driving, the opinions were twofold.

Logger data was compatible for green driving and navigation, and partly for speed information/alert and traffic information. When looking at LFOTs and functions where there were statistically significant differences in logger data, the data was in concordance with questionnaire data for all LFOTs and functions, except for Swedish LFOT2 with navigation.

There were statistically significant results for impact of background variables for age in Finnish LFOT with speed information/alert and Greek LFOT3 with traffic information, for gender in Swedish LFOT2 and transport mode in Finnish, Italian and UK LFOTs with speed information/alert.

4.2.6. H2.6; There is a change in the length of time driven without a break

Data used

FOT	Function/s	Data Type	Number of participants			
			Pre	During1	During2	Post
Finland, LFOT	GD, SI/SA, TI	Questionnaire	GD: 119 TI: 119 SI/SA: 111	59 76 21	43 52 18	56 68 24

Greece, LFOT1-4	NA, SI, SA, TI	Questionnaire	NA:148 SI:134 SA: 136 TI: 134	141 126 124 127	– – – –	137 115 115 118
Italy, LFOT	NA, SI/SA	Questionnaire	NA: 137 SI/SA: 136	117 116	– –	113 112
Spain, Valladolid LFOT	NA, SI/SA	Questionnaire	NA: 118 SI/SA: 118	93 92	96 96	96 94
Sweden LFOT2	GD, NA, TI	Questionnaire	GD: 91 NA: 94 TI: 94	83 82 82	74 77 75	63 68 61
Sweden, LFOT4	TI	Questionnaire	TI: 231	65	–	43
UK, LFOT	NA, SI/SA	Questionnaire	NA: 77 SI/SA: 79	49 48	45 39	42 40

Table 19; Data used for Hypothesis H2.6

Reasons for exclusion of data at FOT level

All test sites where questionnaires have been filled were included in the analysis.

Data selection, filtering and post processing for analysis

The analysis was based on the answers in the questionnaires (pre, during and post) to question “Do you think that any of the following will change / have changed as a result of your access to FUNCTION? [Your time driven without taking a break]”.

Those participants were included who had filled all the questionnaires analysed together

Statistical testing applied

The Friedman Test was used to test for differences between questionnaires. If a difference was found, the Wilcoxon Test with Bonferroni adjustment was used to analyse between which questionnaires the difference existed.

Hypotheses:

H0: There was no change in time driven without a break

H1: There was a change in time driven without a break

Results

FOT	Treatment	Main results
All	Green Driving	No perceived change in time driven without a break
All	SI/SA	No perceived change in time driven without a break
All	TI	No perceived change in time driven without a break
All	Navigation	No perceived change in time driven without a break

Table 20; Summary of results for Hypothesis H2.6

Conclusions from analysis

Questionnaire data was used to assess the hypothesis “There is a change in the length of time driven without a break”. Most participants assessed not to have changed their time driven without a break due to having access to any of the functions. For all test sites and functions, the proportion of answer “no change” increased from pre-test to post-test (from 70–94% to 79–100%). Those who expected or assessed to have experienced a change in the length of time driven without a break assessed a slight increase. For Swedish LFOT2 or LFOT4, the expectations in pre-questionnaire were more commonly towards decrease than increase. However, in the post-questionnaire the results were in line with other FOTs.

There was no statistically significant difference in distribution of previous function use for the ‘increase’ and ‘no change’ groups in Greek LFOT1, which was the only LFOT where the proportion of participants assessing a change to have happened was sufficient for examination.

4.3. SRQ 3 – Does the Device cause Distraction?

The hypothesis associated with this research question is as follows;

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

4.3.1. The duration and / or frequency of glances to defined target areas of the driver's visual scene changes

Data used

FOT	Function / s	Data Type	Number of participants (used)	Total driving km	Total driving hours/minutes
Valladolid DFOT	Navigation, Speed Alert and Speed Information	Logged	32 (20)	500	20 hours
UK DFOT1	Navigation, Speed Alert and Speed Information	Logged	54 (26)	800	30 hours
UK DFOT2	Green Driving, Foot-LITE	Logged	40 (15)	4800	50 hours

Table 21; Data used for Hypothesis H3.1

Safety RQ 3.1 analysis mainly constitutes 3 parts since the analyses use three different but complimentary datasets derived from 3 test sites. Data is derived from two UK test sites and one Spanish test site, close cooperation from the beginning ensured that a level of comparability remained right up to the analysis stage which is borne out by these results. Although endeavours were made to increase the sample size by using other test site data this proved difficult due to the diverse nature of data collection created by remote working.

All sections that follow are split into these test sites as necessary. Despite working to the same experimental design and recording the same types of data all three data analysis took on slightly different forms and although there are some strong similarities between them each will be described separately where necessary.

Reasons for Exclusion of Data (listed by test-site)

Valladolid DFOT

Not all participants were used for the analysis of Spanish data set. A number of participants had missing junctions so were substituted for participants with a full complement of junctions. One trial had corrupted data files which could not be reduced to analysable sections. In addition a small number of other participants were removed as they proved difficult to analyse due to their eyes being obscured by glasses or lighting conditions within the vehicle. In total 12 participants were removed from a dataset of 32 making 20 analysed participants.

UK DFOT1

A number of participants were removed from the sample before any analysis could begin. Due to the positioning of the in car cameras in early trials (effectively a subset of the condition trial) it was not possible for these trials to be analysed. In addition efforts were made to match data to create a between subjects design – unmatched trials were also removed from the analysis. Video where it was impossible to see glance behaviour (i.e. sunglasses or low light) were also removed. In total 34 participants were removed from a dataset of 54 making 20 analysed participants.

UK DFOT2

In total 40 participants completed trials for UK DFOT2; data was excluded for over half of the participants as selection was made on the quality of the video for both the baseline and condition trials. A further smaller subset of participants was also removed as the condition device did not work effectively for the entire test route. In total 25 participants were removed from a dataset of 40 making 15 analysed participants.

Anticipated effect of function to be tested

The combined functions for both UK DFOT1 and Valladolid DFOT will increase both the number and duration of glances to defined targets off road; it is expected that the major increase in these off road glances will be to the navigation system.

For UK DFOT2 it is expected that visual behaviour will change with the addition of the function increasing glances off road.

Anticipated influence of combinations of functions

The effect of the different combinations of functions is unpredictable. No determination has been made between these different function in analysis so the effects when seen will be for the function bundle.

Data Selection, filtering and post processing for analysis (listed by test-site)

The first thing to mention in this section is time. This may seem an unlikely place to start in a section titled as such but as has been borne out by previous studies of this type it is critical that this section of the research is given the appropriate time.

There is a huge amount of information contained in the video of the trials and it is worth spending some effort to extract this. Currently there is no automatic way of achieving this (although steps have been made) so it comes down to manually coding information from the video. This is not the place to describe the intricacies of this process but suffice to say that it is almost impossible to watch all the video recorded.

The reason for mentioning time constraints and video here is that the information in the following section will be skewed towards this method of analysis. Due to the nature of the information contained within the video SRQ 3.1 relied almost solely on this technique.

Valladolid DFOT

In order to gather the information from the Spanish data a selection was made on the Video data. This step necessitated the removal of all continuous data variables (the sensor data). This removal does not take anything away from the safety analysis as it has been conducted from the start without reference to confounding factors such as road conditions or vehicle speed; it is purely an analysis of eye behaviour during the driving trials.

The Valladolid DFOT1 trial uses a continuous data collection approach to record participants navigating a test route using a navigation system, in this respect and in the data it collects it is very similar to the trials conducted in UK DFOT1. Close cooperation ensured that the route type, duration and number of navigable junctions are quite similar.

As has been discussed previously it was not possible to analyse all the video data collected from the Spanish trial, in the same way as the UK DFOT1 trial it was necessary to reduce down the analysis workload to a manageable level but one that contains significant information.

Each trial was reduced from approximately 40 minutes duration to 10 minutes containing 10 carefully selected junctions. It was clear early on however that although careful consideration had been given to comparable test routes in both Spain and the UK it would not be a straight forward process to map a complementary set of junction across both trials

What was also clear from an early stage was that the analysis would have to take a slightly different approach for two small but significant differences between the trials; these are outlined below and help to describe why the data was selected, filtered and analysed as it was.

1. Between subjects design

Unlike the study design used in the UK the Spanish trials used a between subjects design. In total 32 individual participants took part in the driving with an equal split of 17 using the navigation device (the condition trial) and 17 using spoken commands from the experimenter (the baseline trial).

2. Duration rather than Location

Due to this design it was more critical to have comparability on driving duration, or rather the duration of the analysed portions, than to match both the beginning and finishing location as was done in UK DFOT1. In this respect the Spanish data was split into 10 manoeuvre clips of 1 minute duration – the duration was counted back from a junction finish point which remained consistent throughout so that despite slightly different driving distances in the video clips the actual analysed portions were of identical duration.

In doing so it was not always possible to isolate an individual manoeuvre as had been done with the UK DFOT1 data. Some Spanish junctions therefore contain 2 or more combined manoeuvres within a video clip. Due to the durations remaining the same the issue of influencing the data sample (more or less manoeuvres between video clips/participants) was reduced to insignificant levels.

A coding taxonomy was derived to capture the information from the video. Due to slightly lower video quality compared to the UK trials and difficulties in capturing detailed glance information of each participants face a simplified version was derived which simply differentiated between glances 'off road' or glances 'on road'. In addition and where applicable the navigation device was coded separately. A schematic of the coding taxonomy is shown in Figure 3

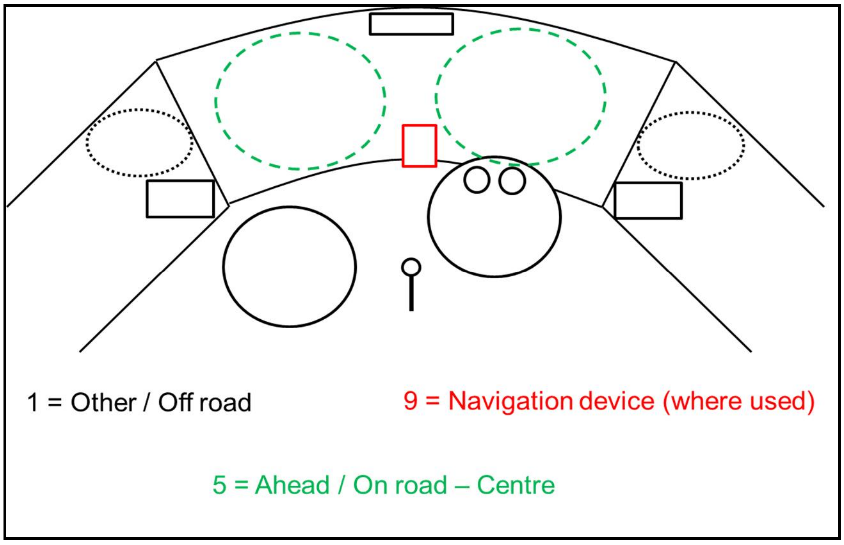

Figure 3; Coding Taxonomy for Valladolid DFOT

UK DFOT1

For this trial the data was presented in 3 main ways; Vehicle/location data, Eye tracking data and Video data, for simplicity these sections will be presented in different sections.

<u>Vehicle data and eye tracking data</u>

A lot of data was removed before the analysis stage. This does not mean that the data was ignored or deleted but that only a small selection of the most useful variables were used in an analysable database. This step ensured that large data quantities of vital data could be handled successfully and quickly without reducing the overall usefulness of the raw data files.

Data were removed for a number of reasons; the most prominent being that it did not help answer the research question ‘does the device cause distraction’. Data that were excluded at this stage came from the whole range of data groups with whole data groups removed in some instances.

Video data

The most major exclusion of data for the video analysis section is the removal of all other continuous data variables (sensor data). Every variable included in Annex I which would normally constitute trial data was excluded for this piece of analysis except GPS longitude and GPS latitude (GPS location) in order to synchronise the video data with the trial route.

As with all DFOT video analysis there was a necessity to reduce the analysis load in UK DFOT1 by selecting periods of video data for analysis. The trial route was designed to include defined sections where, as an analyst, it would seem to be more interesting; this does not mean that periods outside of these are devoid of interest just that in these sections it is possible to ‘guarantee’ useful data.

The trial route was designed around 27 ‘navigation dependant’ junctions; these require the driver to follow the instructions from the navigation device in the car. Not all these junctions are equal, they differ in length, duration, road geometry, speed etc. but some are more repeatable than others and provide more reliable data for analysis.

In total 10 junctions were selected for video analysis, the characteristics of these junctions are described further below but the main effect is that they reduced an average trial duration (and therefore video duration) or 45 minutes down to approximately 8 minutes (depending on traffic flow, holdups etc.)

These 10 analysis junctions had the same general characteristics:

- Clear, unambiguous navigation commands and visuals (not always a certainty with other junctions)
- Long, predominantly straight road leading up to the turn
- Ideally turning off a major road
- Few as possible traffic controls
- The junction was discrete i.e. it was not in combination with any other command

Within each manoeuvre described above there was further exclusion of data. Despite efforts to reduce the number and duration of holdups by careful junction selection it was impossible to remove all periods where the vehicle was stationary. It is debatable whether eyes off road or distraction are still relevant with the vehicle at rest but in the case of UK DFOT1 it was decided that these periods would be removed from the final data (although the video was still coded in effect creating a stationary 'baseline' glance behaviour).

During the trial other subjective measures on driving performance were taken – within this was an 'error' variable recording the success of the manoeuvre. This variable really just recorded whether the junction was successfully taken; errors being when the driver turned too early, too late or did not turn at all. The experimenter in the vehicle would try to keep the subject 'on route' so if additional instructions were given for any reason then an error was recorded at this junction and was subsequently removed from the analysis.

During video analysis it was decided that the last junction in the selected set (and junction 24 overall) was to be removed from the data as it did not fit the criteria outlined in the section above. No other junction was substituted in its place.

A coding taxonomy was derived for the UK DFOT1 video analysis. This system was based in previous successful studies from the USA and kept existing definitions and codes for legacy purposes. The codes used are not sequential but do map over existing studies using these coding taxonomies. Due to the higher quality video used and frame by frame coding methodology it was possible to use many more distraction codes. The most important (and the ones used for analysis) are shown in Figure 4.

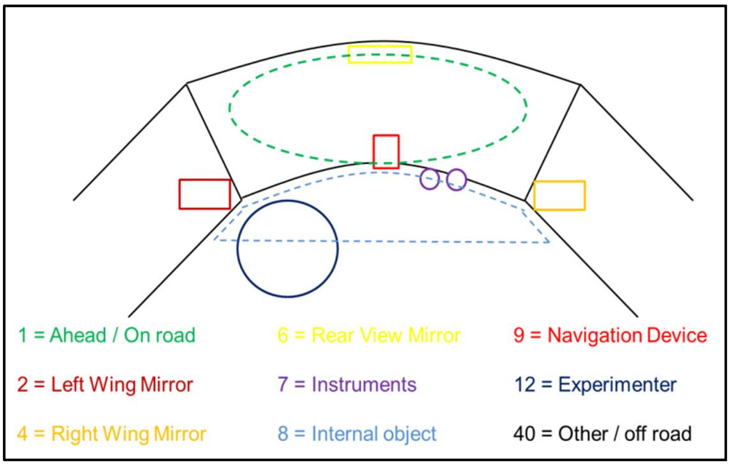

Figure 4; Coding Taxonomy for UK DFOT1

Post processing

Data resolution was recorded for both vehicle data and eye tracking data at the highest level. This step ensured that any subsequent data processing would retain a good level of data even if smoothing or filtering was employed at a later stage. When synchronising the vehicle data (recorded at 100Hz) and the eye tracking data (recorded at 60Hz) it was necessary to reduce the resolution of both to 20Hz.

This step allowed both data sources to be synchronised without the need to average results or interpolate values between points; by employing this technique the 'raw' values will always be returned no matter what analysis is conducted. In some respects this step only reduces variables such as GPS location to an original 20Hz sample; in reality the claimed 100Hz sampling rate is simply interpolated from a 20Hz receiver so the reduction does relatively little to data quality.

UK DFOT2

As has been described previously it was necessary to reduce the quantity of data for the video analysis. In the case of UK DFOT2 where there is no defined 'active' period such as with a navigation device a slightly different approach to data selection was employed.

Data was selected for 3 driving periods of approximately 7 minute duration; these sections were selected based on GPS start and end points to retain consistency and represented motorway, inter-urban and urban settings. Durations differed slightly between participants due to driving speeds and traffic conditions. There was, unlike the UK DFOT1 and Spanish DFOT, no guarantee that the device would be 'active' during the selected period hence the longer duration of analysed period; twice the analysed period of Valladolid DFOT for example.

In line with all other trials described above the video analysis of the data used no sensor data so, apart from GPS location to determine start and end points, all vehicle based and location based variables were excluded from the analysis.

Selection was also made on the analysed output from the video. Despite the video containing a wealth of information it was necessary to reduce the complexity of participant visual behaviour down to a simple coding taxonomy. Figure 5 shows the UK DFOT2 coding taxonomy used to represent the visual scene.

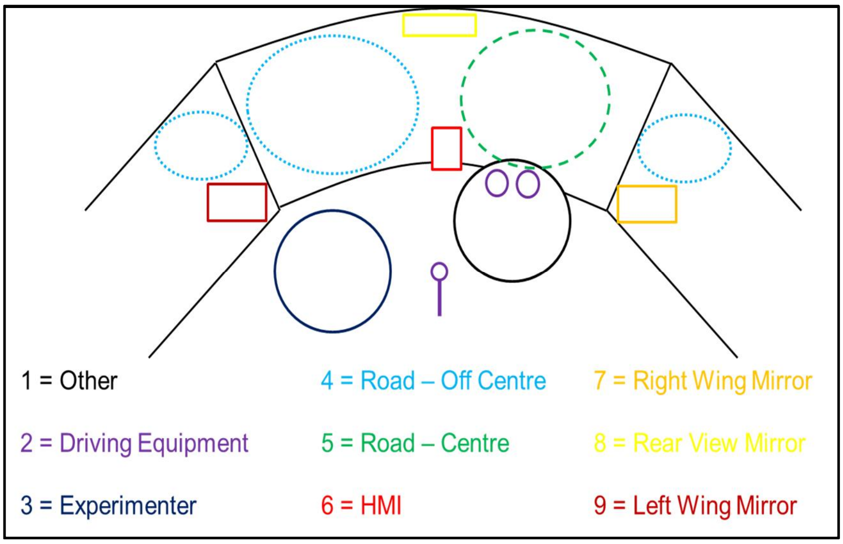

Figure 5; Coding Taxonomy for UK DFOT2

Statistical Testing

The results of the statistical testing for UK DFOTs 1 and 2 and Valladolid DFOT are shown in tables 22a and 22b.

Valladolid DFOT (non-matched pairs)					
Measure	Baseline	Experimental	d.f.	t-test value	significance
Percentage of time with “eyes off road”	9.19%	13.88%	8	9.043	<0.001
Percentage of time with ‘eyes off road’ but not looking at device	9.19%	6.85%	8	-6.510	<0.001
Average duration of glance	0.68 seconds	0.73 seconds	8	2.169	Not significant
Average duration of all glances – baseline to experimental condition (not including the Device)	0.68 seconds	0.73 seconds	8	1.701	Not significant
Average duration of glance – baseline to experimental condition (to the Device only)	0.68 seconds	0.76 seconds	8	2.027	Not significant
UK DFOT1 (matched pairs)					
Measure	Baseline	Experimental	d.f.	t-test value	significance
Percentage of time with “eyes off road”	6.73%	14.3%	8	7.128	P<0.001
Percentage of time with ‘eyes off road’ but not looking at device	6.73%	7.42%	8	0.969	Not significant
Average duration of glance	0.60 seconds	0.71 seconds	8	4.031	P<0.01

Average duration of all glances – baseline to experimental condition (not including the Device)	0.60 seconds	0.65 seconds	8	1.89	Not significant
Average duration of glance – baseline to experimental condition (to the Device only)	0.60 seconds	0.76 seconds	8	4.71	P<0.01

Table 22; Summary of the Statistical Test Results UK DFOT 1 & Valladolid DFOT

	% of glances		Ave glance duration (s)		% total glance duration		Max glance duration (s)		Glances > 2s (n)	
	Control	F-LITE	Control	F-LITE	Control	F-LITE	Control	F-LITE	Control	F-LITE
Centre	47.87	47.5	2.32	2.2	77.98	77.56	19.58	18.41	158.4	156.3
Off road	30.61	21.97	0.54	0.53	12.7	9.52	4.65	5.25	5.53	5.0
Mirrors	9.78	7.49	0.49	0.49	3.99	3.04	1.39	1.38	0.13	0.07
Equipment	7.47	8.04	0.62	0.61	3.63	3.98	1.3	1.3	0.07	0.2
Other	4.17	3.38	0.46	0.64	1.67	1.53	1.06	1.06	0.0	0.13
Foot-LITE	NA	11.37	NA	0.43	NA	4.32	NA	1.28	NA	0.0

Table 23; Summary of the Test Results UK DFOT 2

Summary of Results

The following table summarises the results, full details are available in Annex I.

FOT	Baseline	Treatment?	Main results
Valladolid DFOT	No device – spoken commands from experimenter	Navigation by device	Increase in both frequency and duration of glances off road with treatment.
UK DFOT1	No device – spoken commands from experimenter	Navigation by device	Increase in both frequency and duration of glances off road with treatment.
UK DFOT2	No device – spoken commands from experimenter	Green Driving, Foot-LITE	No change in frequency or duration of glances compared to baseline

Table 24; Summary of results Hypothesis H3.1

Caveats

All trials in all centres were conducted in distinct time periods. As such not all environmental or lighting conditions were experienced.

In order to avoid unnecessary holdups during the trials most were scheduled to fall outside of rush hour periods. As such the data in all three trials could show unnaturally low traffic volumes and are therefore not wholly representative of rush hour or congested driving.

Due to time constraints during the on-road trials there is not always a complete representation of all road types. As an example UK DFOT2 and Valladolid DFOT did include motorway sections whereas UK DFOT1 did not and UK DFOT2 included rural roads which both UK DFOT 1 and Valladolid DFOT did not. In general there is a good match between urban roads however this still is not representative of the National or European urban road system.

UK DFOT1 - Due to the exclusion of some junctions from the test route for analysis purposes it is impossible to say that the junctions used are representative of the road environment as a whole.

UK DFOT1 – The analysis of the UK DFOT1 data concentrated on manoeuvres and as such there is no data on driving between these periods. It is not possible to say that the junctions analysed are representative of driving as a whole.

UK DFOT1 – participant recruitment for the DFOT stage resulted in much lower numbers than expected from the LFOT study. Although the LFOT driver population is relatively representative of drivers as a whole the DFOT participants do not have this characteristic and should not be considered representative of the general driver population.

UK DFOT1 – although great care was taken in the trials to familiarise participants and to give natural responses to the device some effects could be evident from driving a different car or being aware of the instrumentation in the vehicle.

UK DFOT1 – due to the trial routes proximity to Loughborough it must be accepted that some of the participants will be familiar with certain sections of the route. This effect will be small but may be evident on large or complex junctions where unfamiliar drivers will be more cautious compared to a familiar driver.

Valladolid DFOT – Due to the study design (between subjects) it is impossible to compare data between participants, for this reason all data can only be used on a junction basis.

Valladolid DFOT – In addition to the comment above Valladolid DFOT data concentrated on manoeuvres and as such there is no data on driving between these periods. It is not possible to say that the junctions analysed are representative of driving as a whole.

Valladolid DFOT – Some junctions within the whole sample have fewer data records than others (junctions where over half was stationary for example) so in some instances it will not be possible to compare these junctions.

Valladolid DFOT – Because the trial is based on junctions rather than the participants each junctions characteristics may affect the results – for example a motorway section cannot be directly compared to a section of urban street. Careful grouping or matching similar junction layouts will need to be considered before matched junctions can be used.

Valladolid DFOT – although great care was taken in the trials to familiarise participants and to give natural responses to the device some effects could be evident from driving a different car or being aware of the instrumentation in the vehicle.

Valladolid DFOT – due to the trial route being based in and around Valladolid it must be accepted that some of the participants will be familiar with certain sections of the route.

Valladolid DFOT – The analysis technique used on the video data and the quality of the video (particularly of the participants face) may introduce small errors into the data set. This small effect is consistent across the Valladolid data but will make it impossible to compare this data directly with data analysed in different ways from other trials.

UK DFOT2 – The analysed sections of data were selected based on road type and specific GPS locations, as such these sections between participants may differ in duration due to travelling speed – this may have a small effect on the number of recorded 'events' between participants.

UK DFOT2 – Because the data was in effect randomly sampled it is impossible to directly compare the frequency of events (where the test device was active) between participants.

UK DFOT1 – although great care was taken in the trials to familiarise participants and to give natural responses to the device some effects could be evident from driving a different car or being aware of the instrumentation in the vehicle.

Discussion and Conclusions from the Data Analysis

The result on distraction is perhaps the most measurable in relation to safety since eyes off road time increased due to the function and the length of gazes also increased. This was the case for navigation but not for green driving. This can in part be explained by difference in the HMI offered by the two devices, GD is an image associated with a simple response whereas navigation requires more cognitive processing to interpret the information.

It should be noted that it is anticipated that Navigation will increase eyes off road time since it is specifically designed to provide a visual route guide which requires visual attention from the driver. The question remains, what is the impact upon safety?

One could argue that any additional eyes off road time beyond that required to safely operate the vehicle in accordance with for example the rules laid out for the driving test (rear view mirror, side mirror checks etc.) is intuitively a negative in terms of safety, however, as introduced previously, relationships have been suggested between the length of glances away from the road and the risk of accident involvement. These relationships also need to be contextualised with vehicle speed and complexity of road environment which also influence crash risk.

Another point of note is the consideration of some of the alternatives to navigation devices.

Figure 6; Alternatives to Navigation system

Figure 6 illustrates previous methods for unaccompanied navigation which might include consulting a map or a list of printed / written instructions whilst driving. It has not been possible to assess within the TeleFOT project the difference in visual behaviour when using these traditional methods for navigation compared to a Navigation System.

We can therefore only conclude that the NAV function increases eyes off road time when compared to receiving verbal instructions from a passenger which in this context can be construed as a negative impact on safety.

4.4. SRQ 4. Is speed affected?

4.4.1. H 4.1. The number of speed violations/proportion of time spent in excess of the speed limit changes with the access to the Navigation Device.

Data used

FOT	Function / s	Data Type	Number of participants	Total driving km	Total driving hours/minutes
Valladolid DFOT	Speed Alert/Information	Logged	32	500	20 hours
UK DFOT2	Green Driving, Foot-LITE	Logged	40	4800	50 hours
Sweden LFOT2	Speed limit information, Green Driving & Navigation	Logged	100		
Finland LFOT	Speed Information, Traffic Information & Green Driving	Logged	150		
Italy LFOT	Speed Information, Speed Alert & Navigation	Logged	150 + 30 (control group)		
Valladolid LFOT	Speed Information, Speed Alert & Navigation	Logged	120	Over 2.000.000 km (estimated)	

Table 25; Data used for Hypothesis H4.1

Reasons for Exclusion of Data (listed by test-site)

In the UKDFOT2, the Smart driving system Foot-LITE collected data for the entire journey (or at least a large section of it) in both conditions for 28 subjects out of the 40 participants. However for the other twelve it did not log all data or sometimes it crashed during the test and hence these participants were excluded. It was detected that subject

6 had considerable less data compared to the other participants so that data were excluded too.

In Valladolid DFOT data was not registered by the device for one participant.

Sweden LFOT2: Only common trips were analysed in this analysis, this was defined as a journey which was completed 3 or more times in both the Baseline and Intervention periods. This resulted in a total of 6415 journeys being analysed.

Finland LFOT: Only common trips were analysed in this analysis, this was defined as a journey which was completed 3 or more times in both the Baseline and Intervention periods. This resulted in a total of 1728 journeys being analysed.

Italy LFOT: Only common trips were analysed in this analysis, this was defined as a journey which was completed 3 or more times in both the Baseline and Intervention periods. This resulted in a total of 73 journeys being analysed.

Valladolid LFOT: Only common trips were analysed in this analysis, this was defined as a journey which was completed 3 or more times in both the Baseline and Intervention periods. This resulted in a total of 1166 journeys being analysed.

<u>Anticipated effect of function tested</u>

Speed alert and speed information functions will have an effect on the number of speed exceedances and it is expected that both functions will have an impact on the frequency of speed violations and also on the time in excess of the speed limit especially in the long term. It is expected that the rest of the functions tested will not have any impact on speeding.

<u>Anticipated influence of combinations of functions</u>

The effect of the different combinations of functions is unpredictable. If any of the speed related functions are combined with any other function, the combination is expected to decrease speeding times and speeding events, other combinations of functions will have no effect.

<u>Data Selection, filtering and post processing for analysis</u>

Data were selected from UK DFOT2 and Valladolid DFOT based upon the following criteria

- Only select participants whose full set of data where acquired (both conditions baseline/Foot-LITE).

- Speed data between 0.1 km/h-200km/h

Whereas LFOT data were selected according to the following;

- Select the common journeys from the common legs excel file of each country
- Checked that a journey was completed 3 or more times in both the Baseline and Intervention periods
- Only paired journeys were selected
- Speeding events mean was compared among the periods

Statistical Testing

The means from the paired journeys conditions (control and device) of the UKDFOT2 and LFOTs were analysed using a Paired Sample T-test. For Valladolid DFOT it was used a T-test for independent users.

H0: The function has no influence on number of times/proportion of time speeding against the alternative hypothesis

H1: The function decreases the number of times/proportion of time speeding

Results

The following table summarises the results, full details are available in Annex 1.

FOT	Baseline	Treatment	Main results
Valladolid DFOT		Speed Alert/Information	No significant change in number of times speeding
UK DFOT2		Green Driving	No significant change in number of times speeding
Sweden LFOT2		Speed limit information, Green Driving & Navigation	No significant change in number of times speeding
Finland LFOT		Speed Information, Traffic Information & Green Driving	No significant change in number of times speeding
Italy LFOT		Speed Information, Speed	No significant change in

		Alert & Navigation	number of times speeding
Valladolid LFOT		Speed Information, Speed Alert & Navigation	No significant change in number of times speeding

Table 26; Summary of results for Hypothesis H4.1

Caveats

The main concern is that the analysis of the LFOT data were performed using the period of time when the functions were available for use but not the journeys, or the specific times that they were activated. Subsequently care does need to be taken when interpreting findings as a result of using Navigation Devices.

Discussion and Conclusions from the Data Analysis

In general, there were no changes in speed limit compliance due to the use of the Navigation Devices. There were differences in only one section of one of the DFOTs.

The anticipated effect of using SI and SA is not ratified by the LFOT and DFOT data analysed. These functions might contribute to increased speed compliance but not enough to have a significant impact upon well known, common journeys.

H4.2 There is a change in average speed

Data used

Functions and FOTs evaluated are shown in Table 27: Data used for Hypothesis H4.2.

FOT	Function / s	Data Type	Number of participants	Total driving km
UK-DFOT2	GD, FCW, LDW	Logger	40	4910
UK-DFOT3	FCW, LDW	Logger	23	1980

GER-DFOT1	SI/SA	Logger	9	11400
SWE-LFOT2	NAV, GD, TI	Logger	96	653165
SWE-LFOT4	TI	Logger	554	428092
FIN-LFOT2	GD, TI, SI/SA	Logger	140	344000

Table 27: Data used for Hypothesis H4.2

The UK DFOT studies 2 & 3 were specifically designed to help evaluate this RQ by utilising an evaluation route which had three clearly defined sections of road which each included only one type of road category – Motorway, Urban and Inter-urban (Figure 7).

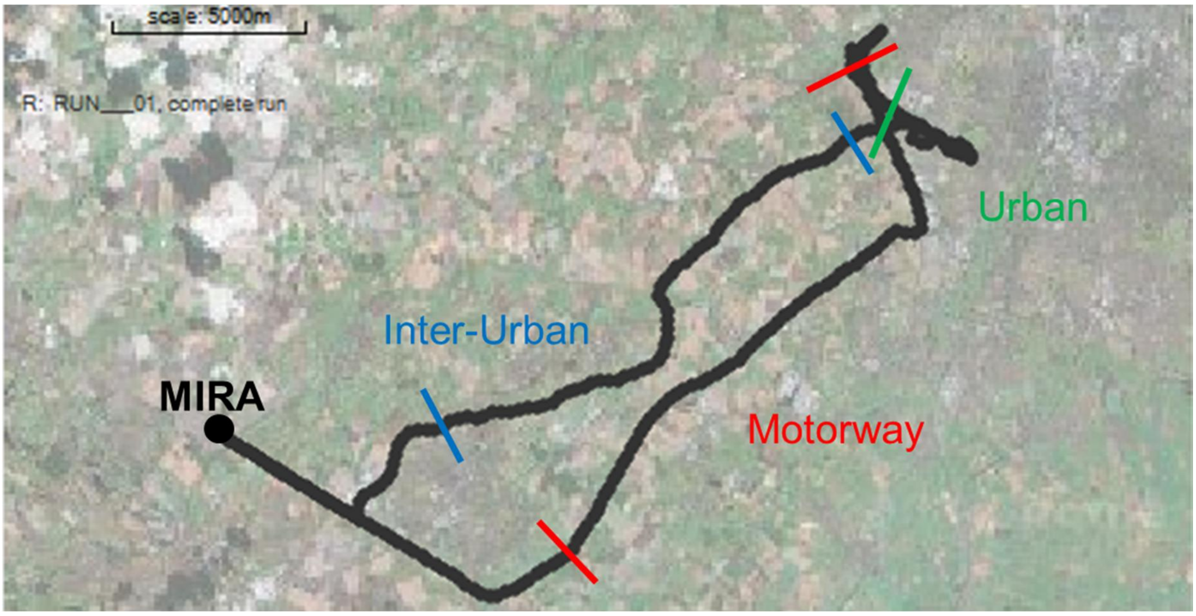

Figure 7: Driving route selected for UK DFOT 2

With UK DOFT 2 the motorway section consisted of 3 or 4 lanes with a speed limit of 70 mph (or 113 km/h), was 18.5 miles (29.8 km) in length and took approximately 11-12 minutes to complete with no junctions/intersections included. The urban section of roadway was completed on unregistered residential single carriageway and one-way roads, and speed limit throughout was 30 mph (48.3 km/h), at 4.1 miles (6.6 km) long and took 8 minutes to complete. Numerous traffic light controlled intersections, roundabouts and T-junctions were included within this section. The inter-urban section linked the two conurbations of Leicester and Hinckley with speed limits of 40, 50 and 60 mph (64.4, 80.5, 96.6 km/h), the main carriage way was all one lane width with multiple lanes at traffic light controlled intersections and roundabouts. This was the longest section of roadway taking approximately 18 minutes to complete at 18.3 miles (29.5 km) in length. The test route for UK DFOT 3 was similar in structure but generally shorter than UK DFOT 2, taking approximately 35 minutes to complete the entire driving scenario. Sufficient time was given before each FOT for drivers to familiarise themselves with both the test vehicle and the nomadic device being evaluated.

With GER DFOT 1 four different driving routes were selected using various road types, with average speed for the entire journey being presented. Drivers were presented with a variety of speed and safety related feedback.

Three LFOTs were used in this analysis, the standard set up for LFOTs were utilised. For this evaluation at least one month of baseline data were analysed before the nomadic device was activated, where a further minimum of three months of driving data were collected and subsequently analysed.

Reasons for Exclusion of Data (listed by test-site)

- UK DFOT 2: Drivers were excluded who did not have values for both the experimental and control conditions. This reduced number from 40 to 35.
- UK DFOT 3: Drivers were excluded who did not have values for both the experimental and control conditions. This reduced number from 23 to 19.
- GER DFOT 1: Drivers were excluded who did not have values for both the experimental and control conditions. This reduced number to 8 participants.
- SWE LFOT 2: Only common trips were analysed in this analysis, this was defined as a journey which was completed 3 or more times in both the baseline and intervention periods. This resulted in a total of 811 journeys being analysed.
- SWE LFOT 4: Only common trips were analysed in this analysis, this was defined as a journey which was completed 3 or more times in both the baseline and intervention periods. This resulted in a total of 475 journeys being analysed.
- FIN LFOT 2: Only common trips were analysed in this analysis, this was defined as a journey which was completed 3 or more times in both the baseline and intervention periods. This resulted in a total of 283 journeys being analysed.

<u>Anticipated effect of function tested</u>

It was anticipated that the effects on average speed for the entire journey when using the different nomadic devices (NDs) reviewed for this analysis would be negligible, or even contradictory, i.e. an increase or decrease with average speed depending on the function being evaluated. It was initially anticipated that average speed for a journey is probably more affected by outside influences such as time of day, traffic density, driver motivations etc., rather than in-vehicle feedback.

It was also anticipated that when using a ND with Green Driving as its primary function average speed will not be affected significantly; other parameters such as speeding, speed consistency and distribution are likely to have more notable effects. However when looking at individual sections of a driving scenario (e.g. motorway, urban and inter-urban) it might expect that an observed decrease in average speed for high speed sections of driving when either speed limit information and speed alerts (SI and SA) are given to the driver. Whilst a decrease in excessive speed or time speeding for any road type is accepted as a positive outcome for road safety with Taylor et al. (2002) suggesting that accident frequency (whether fatal, serious or minor) increases with driving speed to the power of approximately 2.5. In other words, a 10% increase in mean speed would result in a 26% increase in the frequency of all injury accidents. This increases to 30% when considering just KSI (killed or serious injury) accidents (Taylor et al., 2002).

The anticipated effects of using advanced driver assistance systems (ADAS) such as forward collision warning (FCW) and lane departure warning (LDW) are generally unknown. Extensive research has been conducted on driver behaviours such as reliance on automation, skill degradation and driver acceptance. Specifically research into the long-term effects of using ADAS in a naturalistic setting is limited, with research into intelligent speed adaption (ISA) suggesting an increase in frustration and reduced compliance over time (Lai et al., 2010).

The use of satellite navigation systems (NAV) may well be expected to increase average speed of a specific journey; this is because route guidance systems generally construct a route based on shortest time to reach the destination – which will usually involve the use of higher speeds major roads. This routing will lead to an increase in average speed, but not necessary shorter journeys in terms of length. The use of traffic information (TI) feedback is also generally expected to lead to an increase in average speed, due to the avoidance of traffic jams. However, the routing and traffic advice offered by satellite navigation systems will not generally be used for each journey taken, but maybe only unfamiliar or long journeys. This is supported by results from Fowkes and Birrell (2012) which suggest systems being used for less that 25% of journeys in the UK and Sweden. Therefore the potential effects are again unknown. For those journeys where navigation support and TI are used we could expect to see an increase in average speed, however if this would have an overall effect on average speed for all journeys remains unknown.

The anticipated effects of using SI and SA is that occurrences of speed exceedances will decrease, whether this is sufficient to effect average speed for the entire length of journeys or all journeys taken is debatable.

Anticipated influence of combinations of functions

The effect on average speed as a result of a combination of functions is very interesting. The aim of 'eco- driving' is to achieve increases in fuel efficiency without compromising travel time or average speed. Therefore it is anticipated that those FOTs where GD is one of the functions tested will not lead to an effect on average speed. The same could be said for ADAS where limited effect on average speed is expected. With SA and SI a decrease in time speeding is expected but with little chance in average speed.

However, as described previously using a satellite navigation system may be expected to lead to an increase in average speed for a specific journey where navigation advice was taken by the driver. Thus it could be expected that when using NAV, TI or routing information this will override the effects of the other functions tested, leading an increase in average speed where these satellite navigation related functions were used.

Data selection, filtering and post processing for analysis

No further data were excluded or filtered. Mean speed data for all participants (in the DFOTs) and journeys (LFOTs) for each FOT is presented as a single mean value in both the baseline and intervention condition. Only paired journeys were selected, i.e. when a participant completed the same journey in both the control and intervention periods. Given the controlled nature of the DFOTs this was applicable to each participant. With the LFOTs common journeys (defined as a trip being completed three or more times during the period) were matched for each participant in each period, i.e. the average speed for one participant for one common journey was compared across the control to the intervention condition.

Statistical Testing

The means from the paired journeys from the control and intervention conditions were analysed using a Paired Samples t-Test, significance accepted at $p<0.05$. A separate test was conducted for each FOT.

Results

FOT	Baseline	Treatment	Main results
UK DFOT2	-	GD, FCW, LDW	No significant change in average speed
UK DFOT2	-	FCW, LDW	No significant change in average speed
GER DFOT 1	-	SI/SA	No significant change in average speed
SWE LFOT 2	-	NAV, GD, TI	Significant increase in average speed
SWE LFOT 4	-	TI	No significant change in average speed for journey as a whole, significant increase on Urban roads
FIN LFOT 2	TI, TI/SA	GD, TI, SI/SA	No significant change in average speed

Table 28; Summary of results for Hypothesis H4.2

Spread of data

The standard deviation of the mean values for each participant with respect to average speed is presented as error bars on the histograms in Annex 1. As may be expected the spread of the data within the DFOTs was much smaller than in the naturalistic LFOTs were fewer influencing parameters are controlled for. However given the large data sets (upwards of 800 data points) utilised for the analysis the comparatively large standard deviations did not necessarily effect the determination of statistical significance.

Caveats

Care does need to be taken when interpreting average speed findings as a result of using NDs. As well as possibly being a desired behavioural outcome of in-vehicle feedback such decreases in driving speed have also been observed when drivers are engaged in a mobile phone conversation while driving (Alm & Nilsson, 1990; Haigney et al., 2000). This is considered to be a compensatory behaviour in an attempt to reduce workload, as well as increasing perceived safety margins (Haigney et al., 2000), and so could be indicative of increased distraction.

As stated in the introduction changes to average driving speeds are multidimensional, especially with respect to driving efficiency (the focus of this RQ, effects of average speed on safety may well be entirely different). A decrease in average speed on high speeds roads and an increase on low speed roads is deemed more fuel efficient. However the increase in the urban environment should not be achieved by encouraging over-speeding. In addition an increase in average speed should not be accomplished at the cost of increasing the fuel used. You can envisage the situation where in order to maintain higher average speeds a driver uses a higher speed ring-road to drive 20 km to a destination instead of driving 5 km through a town, where duration and distance as well as average speeds are lower.

Discussion and Conclusions from the Data Analysis

Results from UK DFOT 2 showed that no differences were observed with respect to average speed for the journey as a whole, or for the individual sections of roadway analysed. As the ND evaluated in this study was principally a green driving system (combined with safety features of FCW and LDW), a lack of difference with average speed for the journey could be conceived as a positive outcome. One of the reported criticisms made by users/drivers of adopting an eco-driving style is that it is perceived to lead to increased journey time as a result of the driver simply driving slower (therefore lower average speeds

Both SWE LFOT 2 and FIN LFOT 2 also utilised GD as one of the ND functions evaluated in the FOT. Results from these FOTs suggest an increase in average speed calculated over the entire journey (or leg) when evaluating comparable journeys made by the individual participant between the baseline and intervention periods (SWE LFOT 2) and no change (FIN LFOT 2). Due to the combination of functions used with these FOTs drawing specific conclusions is difficult, however the presumption can be made that using a GD does not lead to a decrease in average speed, if anything the data suggest an increase in average speed is possible.

Looking further into the results from the FOTs using GD functions, it can be seen that SWE LFOT 2 showed a significant increase in average speed when driving on urban road types). Results from UK DFOT 2 also suggest a non-significant increase in average speed when driving with the GD system in the urban scenario of 2% compared to the control condition. As well as this possibly being due to any number of external factors, it could be consistent with the aims of the system. Green driving in this context does not aim to slow people down when driving, but more to encourage the appropriate use of gears and limiting excessive accelerations. All of which can be done with little or no effect to travel times. Eco-driving should also encourage the driver to plan ahead and anticipate traffic flow, this not only helps to avoid unnecessary stops but also to maintain a smoother speed profile which can lead to increases in overall speed.

The effect of average speed as a result of using ADAS could not be predicted from reading the available literature, with either an increase or decrease in average speed potentially occurring. This could be as a result of drivers being more willing to push the perceived safety limits by increasing speed due to the ‘safety net’ offered by ADAS. Alternatively the offering of feedback regarding safety limits may have encouraged drivers drive within these limits. Given the two possibilities offered above results suggest that feedback presented to the driver in GER DFOT 1 that no difference in average speed for the journey was observed when using ADAS. The same was true in both UK DFOT 2 and 3) where FCW and LDW feedback were offered to the driver, no changes to average speed were observed. Possible reasons for this lack of differences could be that advanced driver assistance systems that do not offer specific speed related feedback do not affect driving speed. Another possible factor is that safety warning are infrequently activated, thus their effect on ‘normal’ driving is limited. Finally, the lack of difference may be as a result of the ‘controlled’ nature of DFOTs (where ADAS was assessed) with participants driving highly instrumented and potentially unfamiliar test vehicles with examiners also present in the vehicles. This may lead to a more conservative driving style being adopted by test participants, which is likely to include the adhering to posted speed limits and not driving as aggressively as they may do normally. Further research evaluating the use of ADAS in LFOTs will hopefully highlight if any differences occur in naturalistic driving where the driver may feel less as if they are ‘under assessment’ and more likely to drive at their natural speed (whether this is adhering to posted speed limits or not).

The effect of driving with SI and SA systems on average speed is more conclusive. Two of the FOTs used for this analysis adopted speed related feedback, GER DFOT 1 and FIN LFOT 2. GER DFOT 1 revealed no change in average speed when evaluating the use of SI/SA compared to when using ADAS and when both systems were used in combination. FIN LFOT 2 also showed no difference in average speed for the journey when using SI in combination with GD and TI. With both FOTs showing no change in average speed, it would be appropriate to suggest that giving speed related feedback will not lead to any changes in average speed.

The most convincing results come when we consider the effects of driving with TI being offered to the driver and when using a satellite navigation system. All three LFOTs evaluated in this analysis offered TI to their drivers along with other combination of functions. SWE LFOT 2 which evaluated an off-the-shelf satellite navigation system offering navigation as well as TI and GD; SWE LFOT 4 used an application developed specifically for the TeleFOT project (Trelocity Android App) which presented TI and route choice feedback on the users' own Smartphone; and FIN LFOT 2 offers TI, GDS and SI again via the users' own Smartphone. Results from SWE LFOT 2 show that average speed increased from the control phase both for the entire journey and also during urban driving. The only other function used with SWE LFOT 2 was GD which as suggested previously will not lead to an increase in average speed. Therefore we can assume that the observed increase was as a direct result of the TI and NAV feedback offered. Results also suggest that these increases in average speed were more apparent in urban driving, with a 6.7% increase. This is entirely plausible as higher traffic densities will usually be present in the urban environment, where up-to-date traffic information and efficient routing to avoid any potential traffic jams will maximise these benefits. Results from SWE LFOT 4 show a significant increase in average speed of 4.2% when using the ND evaluated, but only in the urban environment. This follows the trends of SWE LFOT 2 where NAV and TI had a greater effect on urban driving where the opportunities for gains are greater. Whilst results from FIN LFOT 2 may not suggest any particular effect of using TI, we need to consider the reference condition which was used as the baseline for this FOT. Rather than with other FOTs where the baseline condition was a period with no ND being used, the baseline for FIN LFOT 2 was either just TI or TI with SA.

Therefore no difference between the control and experimental phase adds credence to that fact that GDS and SA have little effect on average speed.

Conclusions for 'Is average speed affected' as determined from this analysis are in general that minimal differences were observed. Only two of the FOTs analysed revealing significant changes in average speed (SWE LFOT 2 and 4). The DFOTs revealed no significant differences either over the entire journey or individual route sections analysed. With the LFOTs no differences were observed when driving through intersections, with two of the three showing a change with urban driving. In total of the 17 road section x FOT combinations analysed only three (18%) revealed a significant difference to average speed as a result of the ND used. It was particularly difficult to assess the effect of individual functions (GD, TI, etc.) given the combination of functions used in the FOTs; however some conclusions can be interpreted based on the analysis of the data used in this chapter, these are:

- the use of GD does not lead to a reduction in average speed, with one FOT actually showing an increase,
- no effects were observed when using ADAS,
- using SI/SA systems are likely to have no effect on average driving speed,
- any increase in average speed, both for the entire journey and also in urban driving, is likely to be as a result of the driver being offered TI and more efficient routing in order to avoid areas of high traffic densities.

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

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

Included within H5.2

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

The purpose if this research question is to investigate the users' perception about the vehicle lane positioning and the impact of the function on it.

<u>Data used</u>

The data that have been used are the data from questionnaires administered at Large Scale test sites. The aim is to investigate the users' perception about the vehicle lane positioning and the impact of the function on it. Descriptive statistical analyses have been performed for all Large Scale test sites.

FOT	Function / s	Data Type	Number of participants
IT LFOT	NAV / SI / SA	Questionnaires Test group	137
SPA LFOT	NAV / SI / SA	Questionnaires	116
FI LFOT	GD / SI / SA	Questionnaires	131
UK LFOT	NAV / SI / SA	Questionnaires	77

GRE LFOT	NAV (LFOT1) SI (LFOT2) TI (LFOT 3) SA (LFOT4)	Questionnaires	147
SWE LFOT 1	GD / SI / SA	Questionnaires	55
SWE LFOT 2	NAV / GD / TI	Questionnaires	91
SWE LFOT 4	TI	Questionnaires	258

Table 29; Data used for Hypothesis H5.1 and H5.2

<u>Reasons for exclusion of data at FOT level</u>

All data gathered through questionnaires were involved in the analysis, but selection and filtering were then applied according to performed statistical analyses.

No objective data about lane positioning (longitudinal and lateral) have been collected at Large Scale FOTs.

<u>Anticipated effect of function to be tested</u>

For both Navigation Static and Speed Alert/Speed Limit information functions, it is anticipated that they will not affect vehicle positioning within the lane when travelling.

For Green Driving function, it is anticipated that it will not affect vehicle positioning within the lane because it does not refer to external factors but mainly to driving style. Maybe a more efficient driving style (i.e. less fuel consumption due to relaxed driving style in acceleration and braking driving phases), could impact on longitudinal vehicle positioning within lane.

For Traffic Information function, it is anticipated that it will not affect vehicle positioning within the lane because it does not refer to external factors but mainly to driving style.

It is anticipated that vehicle positioning within the lane could be affected during user interaction with the Nomadic Device (for all functions when user interaction is required) due to possible cognitive distraction. User interaction with ND becomes a secondary task performed while driving.

Anticipated influence of combinations of functions

Questionnaire responses considered impact of only single functions.

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")
     - o Difficulty positioning the vehicle with respect to lane
     - o The distance to a vehicle ahead got smaller than acceptable
2. Users filling-in POST questionnaire.

Statistical testing applied

Descriptive statistics has been used since a single answer at POST questionnaire has been considered during analysis.

Results

FOT	Treatment	Main results
All	Green Driving	Little or no impact on longitudinal or lateral positioning
All	SI/SA	Little or no impact on longitudinal or lateral positioning
All	TI	Little or no impact on longitudinal or lateral positioning
All	Navigation	Little or no impact on longitudinal or lateral positioning

Table 30; Summary of results from Hypothesis H5.1 and H5.2

Conclusions from analysis

a) Italian Large-scale FOT

About the impact of accessing functions on vehicle positioning within the lane:

- Users perceive Navigation system as rarely or very rarely impacting on vehicle lane positioning (both lateral and longitudinal).
- Users perceive Speed Limit / Alert as having no or low impact on lane positioning (both lateral and longitudinal).

b) Spanish Large-scale FOT

About the impact of accessing functions on vehicle positioning within the lane:

- Users perceive Navigation system don't affect longitudinal lane positioning while it affect occasionally the lateral lane positioning
- Users perceive that Speed Limit / Alert had no impact on lane positioning (both lateral and longitudinal).

c) Finnish Large-scale FOT

About the impact of accessing functions on vehicle positioning within the lane:

- Users perceive Speed Limit / Alert as having no or low impact on lane positioning (both lateral and longitudinal).
- Users perceive that green driving support system as having no or low impact on lane positioning (both lateral and longitudinal).
- Users perceive Traffic Information as low impact on lane positioning (both lateral and longitudinal). Furthermore longitudinal and lateral positioning are perceived as equally affected by the usage of ND with Traffic Information function.

d) UK Large-scale FOT

About the impact of accessing functions on vehicle positioning within the lane:

- Users perceive that Navigation systems do not affect longitudinal lane positioning while occasionally affecting lateral lane positioning
- Users perceive Speed Limit / Alert as having no or low impact on lane positioning (both lateral and longitudinal). Longitudinal lane position appears to be affected little by this function.

e) Greek Large-scale FOT

About the impact of accessing functions on vehicle positioning within the lane:

- Users perceive Navigation system as rarely or very rarely impacting on vehicle lane positioning (both lateral and longitudinal).
- Users perceive Speed Limit as having no impact on lane positioning (both lateral and longitudinal).
- Users perceive Speed Alert as rarely or very rarely impacting on lane positioning (both lateral and longitudinal).
- Users perceive Traffic Information as rarely or very rarely impacting on lane positioning (both lateral and longitudinal). Furthermore longitudinal and lateral positioning are perceived as equally affected by the usage of ND with Traffic Information function.

f) Swedish Large-scale FOT

About the impact of accessing functions on vehicle positioning within the lane:

- Users perceive Navigation system as rarely or very rarely impacting on vehicle lane positioning (both lateral and longitudinal).
- Users perceive Speed Limit / Alert as having no impact on lane positioning (both lateral and longitudinal).
- Users perceive that green driving support system as rarely or very rarely impacting on lane positioning (both lateral and longitudinal).
- Users perceive Traffic Information as having no impact on lane positioning (both lateral and longitudinal).

From the perceptions of participants, there is no indication that the TeleFOT functions will have an impact on safety.

A further analysis of headway has been undertaken as part of the Efficiency impact assessment (D4.5.3). Here logged data were used to evaluate the hypotheses

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

EFF-H4.2 Distance from the preceding vehicle is likely to increase/decrease (when device is used compared to when device is not used)

In these analyses some there were some significant changes in the time headway and also the standard deviation of the time headway when comparing TeleFOT functions and ADAS in various combinations.

An explanation for some differences between the perceived and logged results can be given as;

- Different data sources(questionnaires vs. logged data) were used in analysis
- Different sites were included (LFOTs vs. DFOTs)
- Longitudinal control from questionnaires is probably translated into “perceived gap”. Gap (front-rear distance) is a different indicator from time headway and distance headway (front –to- front distance).
- ADAS were included in DFOTs

4.6. SRQ 6. Is braking affected?

4.6.1. H6.1 The device changes braking behaviour

Data used

FOT	Function / s	Data Type	Number of participants / (analysed)
German DFOT 1	Static Navigation / SI/SA, ADAS	Logged	9 / (8)
Greek DFOT	Static Navigation / SI/SA, ADAS	Logged	8
UK DFOT 2	GD	Logged	40 / (28)
Greek LFOT 1-4	NAV, SL, TI, SA	Logged	14

Table 31; Data used for Hypothesis H6.1

Reasons for exclusion of data at FOT level

The same criteria for exclusion of data are taken into account for all DFOT test sites. Only those subjects who completed the baseline condition as well as the treatment condition(s) are considered for the analyses. Some more boundary conditions are considered for the analysis of the LFOT data. Only subjects who have more than twenty logged legs and at least one leg in every condition can contribute to the analysis of the braking behaviour. Furthermore, it is essential to find common origin-destination pairs which can be compared. The quality of the logged data must also be checked.

Anticipated effect of function to be tested

It is anticipated that speed limit information will have a different effect on the driving behaviour than speed limit alert. With speed limit information the driver is constantly informed about the speed limit on; harsh braking manoeuvres therefore should be avoided since there are no sudden (or unexpected) speed limit changes. Speed limit alert could evoke another braking behaviour; being only activated when the vehicle is recorded as travelling over the set limit. The alert could lead to harder braking situations.

Green driving support system could lead to a more harmonic driving style; without unnecessary accelerations and decelerations, to save fuel, it can be anticipated that the GD function avoids hard braking manoeuvres.

Anticipated influence of combinations of functions

As mentioned in the section above, speed limit information and speed limit alert might have contrary effects on braking behaviour. The systems used at the German test site cannot be used separately, so it is anticipated that there will not be a noticeable influence due to these functionalities. The Greek test site can separate their functions, so the effect mentioned above can be proved with the data of the Greek DFOT.

The green driving function at the UK test site is combined with Lane Departure Warning (LDW) and Forward Collision Warning (FCW). The GD function cannot be used separately, so all three functions must be considered as one application. No influence of combination of functions can be considered furthermore.

Data selection, filtering and post processing for analysis

Data were selected from each FOT based upon the following criteria

Logged data

- DFOT:
  - German DFOT: 12 trips / subject with 3 configurations (only NAV/SI/SA, only ADAS, combination of both)
  - Greek DFOT: (baseline, NAV+ADAS, NAV+ADAS+SA, NAV+ADAS+SI)
  - UK DFOT 2: 2 trips / subject with 2 configurations (baseline, treatment)
- LFOT:
  - Subjects with logged legs during every condition have been considered

Results

FOT	Baseline	Treatment?	Main results
German DFOT 1		Static Navigation / SI/SA, ADAS	No change in braking behaviour
Greek DFOT		Static Navigation / SI/SA, ADAS	No change in braking behaviour
UK DFOT 2		GD	No change in braking behaviour
Greek LFOT 1-4		NAV, SL, TI, SA	No change in braking behaviour

Table 32; Summary of results for Hypothesis H6.1

Conclusions from analysis

After analysing three DFOTs and one LFOT, it could not be confirmed that any of the functions of the nomadic device changes braking behaviour of the subjects. There are some statistical significant changes, but it is not reasonable to reduce those changes to the functionalities of the nomadic device. They could not be verified by other data and the amount of available data was not great enough to make a reliable statement regarding the influence of the nomadic device on the braking behaviour.

4.7. SRQ 7. Is non-driving manual activity affected?

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

The analysis has been based on data collected in the Italian DFOT

FOT	Function / s	Data Type	Number of participants	Total driving km	Total driving hours/minutes
Italian DFOT	Navigation Traffic information Green Driving	Logged + hands and eyes videos	49 (*)	3800	80 hours
(*) the data of one participants were excluded					

Table 33; Data used for Hypothesis H7.1

Reasons for exclusion of data at FOT level

All the data were considered except that related to participants whose data were apparently incongruent.

Anticipated effect of function to be tested

It was expected that all the functions could have an impact on the duration of hands-off wheel time when active.

Anticipated influence of combinations of functions

The effect of the combinations of functions was tested only for Traffic Information and Navigation; these two functions were active together, but, as far as the analysis of SRQ7 is concerned no interference is expected.

There is an anticipated impact for green driving combined with traffic information and/or navigation; the impact is most likely to be evident when switching from one function to another. Unfortunately, for safety reasons this could not be tested because it was expressly requested for drivers not to do this operation while driving.

Data Selection, filtering and post processing for analysis

All Italian DFOT data, where good data existed, were selected. One participant's data was excluded for this reason.

The CANApe tool by Vector was used for both acquisition and analysis. It provides a "parallel" analysis capable of displaying synchronized data and video windows (see Figure 8; Typical CANApe page below)

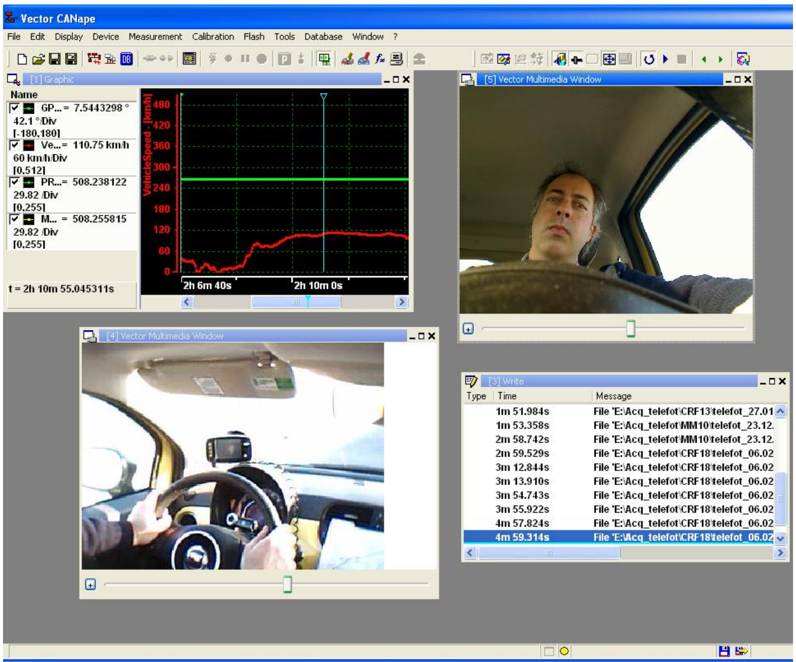

Figure 8; Typical CANApe page

The analysis was then performed manually, looking for "hands off the steering wheel" situations and correspondingly verifying the reason (whether it was or was not due to the active function at the considered instant).

The initially planned overall process had 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.

<u>Statistical Testing applied</u>

The initially planned tests where finalized to verify one of these two hypotheses

- H0: The functions increases the duration of hands off wheel time
- H1: The function decreases the duration of hands off wheel time

Due to the specific results obtained, the duration of hands off wheel time due to direct operation of the device was related to a single action.

The influence of active functions on duration of hands off wheel time was evaluated in the highway stretch for Navigation, comparing baseline and active functions (treatment), using the t-test.

In the urban stretch the greatest "duration of hands off wheel time" was due to gear-shifting. In principle a different number of gear-shifting could be induced by "green driving". It was assumed that traffic conditions were equivalent in baseline and treatment and a separate comparison was made on a selected urban stretch also using the t-test.

Results

Based on results the significance related to the Traffic Information is 100%, because all drivers accepted the system input and confirmed with a manual operation.

No significant difference was found for the "duration of hands off wheel time" for all the other behaviours with the two performed t-test ("navigation - on highway" and "green driving – urban")

FOT	Baseline	Treatment?	Main results
Italian DFOT	No function	Navigation	No significant impact in hands off wheel time
Italian DFOT	No function	Traffic Information	100% interaction when TI activated but not significant when compared to all other hands off road actions
Italian DFOT	No function	Green Driving	No significant impact in hands off wheel time

Table 34; Summary of results from Hypothesis H7.1

Contextual discussion

There are a number of comments relating to the experimental nature of the study.

- The recommendation to avoid reprogramming while driving, for safety and ethical reasons, was explicitly given in the instruction of our trial, while in more general situations this safety recommendation could not be respected by the user. This type of behaviour can only be realistically observed in a naturalistic study. In such a study and for this specific purpose the hand observation could be sufficient to detect the unsafe behaviour.
- In general there is a direct link between distraction time and “hands off wheel” but not at a quantitative level. The timing is different because workload increases before the beginning of the manual action and could continue after the end of the manual action. In this sense the hand observation may be considered useful only if there is a parallel evaluation of the timing correlation between a specific command and the real distraction and each registered command. This precise correlation was not found in the specific command observed in our DFOT.
- According to further discussion among experts and participants having experience with navigation; distraction/anxiety may rise when the driver has not total confidence about the reliability of information provided by the device. This lack of confidence may be caused by:
    - Short experience (new users)
    - Obsolete maps → wrong indications
    - Incongruent information between navigator and a traffic sign indication.

  As well, misinterpreting or ignoring the navigator instructions could lead to the same psychological situation. An increase in workload happens at a different degree depending on the driver’s characteristics.

In this DFOT the short experience was balanced by accurate pre-instruction and the other two points were in theory absent thanks to the pre-tested route.

On the contrary two cases were present in which the driver misinterpreted the instructions, although he re-entered the navigation route very rapidly following the new instructions. In both cases no special distraction signs were observed.

It should be underlined, as already reported in D4.3.2, that other manoeuvres, where the driver does not keep the hands on the steering wheel, were detected:

- Driving with the right hand placed on the gearshift lever, or in any case driving with a single hand (normally the left one). This is quite a common habit. This behaviour might not be considered critical in some situations (e.g. low speed driving in an urban setting), but maybe more dangerous while driving on highways at high speed. Among the participants it was found that 11 had this driving style for more than half of the highway driving duration. For each driver there was no significant difference between baseline and treatment situations. Moreover in 3 cases the driver sometimes placed the left hand on the right half of the steering wheel (figure 10).
- Cellular phone usage. This behaviour was observed in three cases.
- On board multimedia system control (even if for some operations steering buttons where available).
- Consulting paper instructions.
- Air conditioning system regulation and/or check the air from the air vents.
- Adjusting the internal rear view mirror.

Figure 9; Images of 'hands off' steering wheel situations

- Adjusting the sun visor.
- Combing hair with their hand whilst looking at the internal rear mirror and driving at high speed.

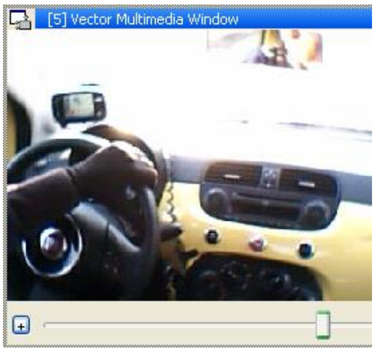

Figure 10; Crossed single hand driving

Caveats

No special background factor should influence the analysis, but, the “safe mode” for navigation and the controlled test could have hidden potential critical and unsafe conditions which could potentially happen in more general situations.

Conclusions from analysis

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

The fact that consultation of the paper instructions was detected while driving in the baseline phase could be considered a point in favour of navigation support, because in the “pre navigator” era it was quite frequent to see drivers consulting maps or instructions while driving.

Based on current results the hands monitoring may be a help but not a complete alternative to other methods for checking the distraction due to a device.

The policy of inhibiting the device reprogramming while the vehicle is moving is a good protection against the unsafe use of devices.

4.8. Mobility MRQ11.1- Is there a change in feeling of subjective safety?

The implications are that any mobility management intervention is likely to affect people in different ways based on their susceptibility to change behaviour and stage position within the behavioural change process. Further, evaluations that focus on behavioural change as such would not detect any of the subtler attitudinal and perceptual changes that would also occur as people progress to later stages of readiness to change (Carreno and Welsch, 2009).

In this analysis, participants were asked in the user uptake questionnaires whether they thought their ‘safety’ during driving would change following installation of the device that was tested in the FOTs. In particular 4 functions were assessed – Green Driving Advisory systems, Navigation systems, Speed Alert systems and Traffic Information systems. The participants were asked to rank the likely changes in perception of safety on a 5-point scale where ‘1’ represents a ‘radical decrease’ in perception of safety and ‘5’ represents a ‘radical increase’ in perception of safety.

Hypothesis

The following Hypotheses have been addressed in this analysis;

M-H11.1 There is likely to be an increase in user feeling of safety

M-H11.1 There is an increase in user feeling of safety

Data used

Data were used from the test-sites shown in the following table. Different functions were tested at the test-sites. In total, the test-sites tested 685 participants and between them some 2,172,225 kilometres of driving were recorded.

FOT	Function / s	Data Type	Number of participants	Total driving kms
Sweden	Green Driving Static Navigation Traffic information	User Uptake Questionnaire	98	513,840
Spain,	Static Navigation Speed alert	User Uptake Questionnaire	116	867,729

Valladolid				
Italy	Static Navigation Speed alert	User Uptake Questionnaire	117	168.677
Greece	Static Navigation Traffic Information	User Uptake Questionnaire	148	288,762
UK	Static Navigation Speed alert	User Uptake Questionnaire	80	185,779
Finland	Green driving Speed alert Traffic Information	User Uptake Questionnaire	126	315,946
Total			685	2,172,225

Table 35; Data used for Mobility H11.1

Reasons for Exclusion of Data (listed by test-site)

For all test-sites, participants were only included in the analysis contained within this report if they completed all questionnaires at each stage within the FOTs (i.e. 'Before', 'During' and 'After)'*. This led to the exclusion of a number of participants as follows;

Test Site	Sweden	Spain	Italy	Greece	Greece	UK	Finland
FOT	SFOT	SP-FOT1	I-FOT1	GR-FOT1	GR-FOT3	UK-FOT1	FI-FOT1
Total number of FOT Participants	98	116	117	148	148	80	126
Number who completed all Questionnaires	58	83	108	127	59	34	33

Numbers excluded in the analysis	40	33	9	21	24	46	93

Table 36; Participant questionnaire responses MH11.1, reasons for exclusion

*NB - In both Spain and Finland, there were 2 'During' phases – 'During1' and 'During2'

Situational Variables

Because the analysis was dependent upon the participants completing all stages of the questionnaire in order to test for an effect of the function, the influence of "situational variables" including journey details, gender, age, driving experience, previous familiarity with the device etc. could not be satisfactorily tested. This is because it was necessary to discard the responses of the participants who did not complete all stages.

Anticipated effect of functions tested

It was expected that the introduction of the devices would increase participants' perception of safety as the devices provide information to the drivers which is supposed to facilitate the driving task. The result is that the driver has more time to focus on driving through the effect of the device and does not need to focus on aspects such as navigation, speed, etc.

Anticipated influence of combinations of functions

For this hypothesis, the two functions provided by the system in the Italy, UK and Spanish FOTs can be treated independently. Navigation support is expected to have no effect and hence any effect observed could potentially be attributed to speed alert only.

Green driving is not part of a combination of functions and hence any effect seen in this data analysis is due to the green driving support function alone.

Data Selection, filtering and post processing for analysis

The data filtering was as described above. Some processing of the data was required to ensure that matched subject data was derived.

Statistical Testing

Non-parametric statistical tests were used to analyse the data. As the data collection involved rankings according to a Likert Scale, A Friedman test was chosen as the most suitable non-parametric test for data analysis.

The following hypotheses were applied;

H0: The participants' perception of safety does not change after using the device for several months within the FOTs

H1: The participants' perception of safety changes after using the device for several months within the FOTs

Results

(Concluded from final questionnaire responses)

FOT	Treatment	Main results
All	Green Driving	No influence on perception of safety
All	SI/SA	Slight increase in perception of safety
All	TI	No influence on perception of safety
All	Navigation	No influence on perception of safety

Table 37; Summary of results for mobility Hypothesis H11.1

Conclusions from data analysis

On the whole, FOT participants were either neutral or relatively positive about the impact that after-market devices would have on their perceptions of safety. In other words, the participants tended to expect the devices to either make "no change" or would "slightly increase" their perceptions of safety.

Experience with the devices tended to change the participants' impression and perceptions of safety. In the some cases, user experience led to the participants concluding that the device would make no overall change to their perception of safety (e.g. Navigation system in Sweden and the UK, Traffic Information in Greece, Sweden and Finland, Speed Alert in the UK and Finland, Green Driving in Sweden and Finland).

In other cases, the user experience led to respondents reporting that their perceptions of safety tended towards "no change" during the FOT but by the end of the FOT, their perceptions had changed again in that there was a slight increase in the numbers reporting that the device would "slightly increase" perceptions of safety (e.g. Navigation system in Italy, Spain, Greece and the UK, Speed Alert in Italy, Spain and the UK).

Respondents in Spain, Italy and the UK had a very strong perception that a Speed alert system would increase their perception of safety whilst driving with over 50% of respondents at each of these test-sites reporting this. However, user experience led to this perception changing somewhat. Nevertheless, in Spain, by the time of the third questionnaire response, a high percentage indicated that the speed alert device would "radically increase" their perception of safety although this level declined at the post-test stage.

Overall, hardly any of the participants responded that they thought that any of the devices tested would have a "radical decrease" on their perception of safety. Some participants did indicate that the devices would "slightly decrease" their perceptions of safety, although numbers reporting this were low. .

For the Navigation function overall, there was some initial optimism that the function would "slightly increase" perceptions of safety at all test-sites. However, following this initial optimism, respondents tended to change their response to "no change" in perception of safety mid-way through the FOT. However, with the exception of the Swedish FOT, by the end of the FOTs, many participants responded that the function *did* in fact "slightly increase" their perception of safety.

For the traffic information function, there was much initial optimism amongst the participants that the function would increase their perception of safety. However, at each test-site, this initial optimism was not maintained and by the end of the FOTs, most participants responded that the function made "no change" overall to their perception of safety.

For the speed alert function, there was the greatest optimism that perceptions of safety would "slightly increase'". At all test-sites, this initial optimism changed mid-way through the FOTs but not substantially and by the end of the FOTs, many respondents still believed that the function "slightly increased" perceptions of safety (38% in Spain, 42% in Italy, 42% in the UK and 22% in Finland).

For the green driving advisory function, there was high expectation that the function would “slightly increase” perceptions of safety with over half of the participants reporting that they thought this to be the case (52% in Finland). However at the Finnish test-site, this initial optimism was not maintained.

Overall, little general effect of background variables could be found on changes in perception of safety from the relatively positive expectations (of ‘increasing perception of safety’) before the FOT had started to ‘no change’ in perceptions of safety once the FOT had been completed. This was true for all test-sites where the perception changed by more than 20% between the ‘before’ phase to the ‘after’ phase.

When looking at respondents’ perceptions of safety at the end of the FOT (in other words disregarding responses gathered before and during the FOTs), some effects of background variables were found, particularly in terms of driving experience in Italy and Greece - but overall, it was found that the background variables did not particularly affect perceptions of safety.

5. SUMMARY OF RESULTS BY FUNCTION

This section summarises the results by function. As discussed in the method section, under each function only results relating to single function are included.

5.1. Navigation

Route Choice

- *LFOT Questionnaires, perceived slight increase in use of rural roads, no effect on highway use*
- *SPLFOT1 Increase in use of city roads*

Distance Travelled

- Greece LFOT1, no significant change in mean distance between comparable origins and destinations
- LFOT Questionnaires, no perceived change in number of journeys
- *LFOT Questionnaires, some perception distance travelled is decreased*
- Greece LFTOT 1, No significant influence on comparable journey duration
- *LFOT Questionnaires, Perceived change in journey duration (shorter)*
- LFOT Questionnaires, No perceived change in time driven without a break

Distraction

- *UK DFOT1 / Valladolid DFOT increase in the percentage of eyes off road time*
- *UK DFOT1 / Valladolid DFOT Increase in the average glance duration*

Speed

- Not assessed as single function

Lane positioning

- LFOT Questionnaires, Little or no effect on lane positioning

Braking behaviour

- German DFOT1, no significant change in braking behaviour
- Greek DFOT, no significant change in braking behaviour
- Greek LFOT, no significant change in braking behaviour

Manual activity

- Italian DFOT, no significant increase in hands off road time

5.2. Speed information/alert

Route Choice

- LFOT Questionnaires, no perceived effect on road type choice

Distance Travelled

- Finland LFOT, no significant change in mean distance between comparable origins and destinations
- Greece LFOT 2, no significant change in mean distance between comparable origins and destinations
- Greece LFOT 4, no significant change in mean distance between comparable origins and destinations
- LFOT Questionnaires, no perceived change in number of journeys
- LFOT Questionnaires, no perceived change in distance travelled
- Finland LFOT, No significant influence on comparable journey duration
- Greece LFOT 2/4, No significant influence on comparable journey duration
- LFOT Questionnaires, No perceived change in journey duration
- LFOT Questionnaires, No perceived change in time driven without a break

Distraction

- Not assessed

Speed

- Valladolid DFOT, no significant change in average speed
- GEDFOT 1, no significant change in average speed
- Valladolid DFOT, no significant change in incidence of speed violation

Lane positioning

- LFOT questionnaires, Little or no effect on lane positioning

Braking behaviour

- German DFOT 1, no significant change in braking behaviour
- Greek DFOT, no significant change in braking behaviour

- Greek LFOT, no significant change in braking behaviour

Manual activity

- Not evaluated

5.3. Traffic information

Route Choice

- *SEFOT4, Significantly more rural roads*
- *LFOT Questionnaires, no perceived effect on highway use, slight increase in rural road use*

Distance Travelled

- Madrid LFOT, no significant change in mean distance between comparable origins and destinations
- Sweden LFOT 4, no significant change in mean distance between comparable origins and destinations
- Greece LFOT 3, no significant change in mean distance between comparable origins and destinations
- LFOT Questionnaires, no perceived change in number of journeys
- LFOT Questionnaires, no perceived change in distance travelled
- Sweden LFOT4, No significant influence on comparable journey duration
- *Greece LFOT3, Significant influence on comparable journey duration (shorter)*
- *LFOT Questionnaires, Perceived change in journey duration (shorter)*
- LFOT Questionnaires, No perceived change in time driven without a break

Distraction

- Not assessed

Speed

- Sweden LFOT 4, no significant change in average speed for journey as a whole, significant increase on Urban Roads

Lane positioning

- LFOT questionnaires, Little or no effect on lane positioning

Braking behaviour

- Greek LFOT, no significant change in braking behaviour

Manual activity

- Italian DFOT, no significant increase in hands off wheel time

5.4. Green driving

Route Choice

- *LFOT Questionnaires, perceived very slight decrease of highway use and increase of rural road use. (about 5% of participants reported a slight increase or decrease)*

Distance Travelled

- Finland LFOT, no significant change in mean distance between comparable origins and destinations
- Madrid LFOT, no significant change in mean distance between comparable origins and destinations
- LFOT Questionnaires, no perceived change in number of journeys
- LFOT Questionnaires, no perceived change in distance travelled
- *Finland LFOT, Significant influence on comparable journey duration (longer)*
- LFOT Questionnaires, No perceived change in journey duration
- LFOT Questionnaires, No perceived change in time driven without a break

Distraction

- UK DFOT2, no significant change in visual behaviour

Speed

- UK DFOT 2, no significant change in average speed for urban roads and motorways
- Finland LFOT2, no significant change in average speed

Lane positioning

- LFOT Questionnaires, Little or no effect on lane positioning

Braking behaviour

- UK DFOT 2, no significant change in braking behaviour

Manual activity

- Italian DFOT, no significant increase in hands off road time

6. DISCUSSION ON IMPLICATIONS FOR SAFETY

In the introduction section a range of indicators for safety where introduced and discussed through a review of existing literature. In this section we consider the results that indicate a change by function as listed in section 5 in parallel with the implication for safety of any change in the indicator of safety according to the literature. Note that implications are based solely on results relating to single function use. As stated previously, there is as yet no clear and common methodological agreement within the research community for handling this issue; The FOT-NET networking activity is currently developing guidelines for future FOTs and Naturalistic Driving Studies.

It is important to realise that the TeleFOT trials were not designed to measure safety in relation to accidents and injury outcomes with function use, clearly it is hoped that

<u>Navigation</u>

The results of the analysis indicate that navigation has an effect in the following areas; distance travelled, route choice and distraction.

In relation to distance travelled, the result indicating change is based upon participants perception rather than logged data. Participants felt that both the length and the duration of journeys had decreased with use of Navigation. For the logged data, comparable origin / destination journeys were selected which by its nature predisposes the analysis to what might be considered 'regular' or 'commuting' journeys. It is unlikely that navigation would have had an effect on this type of journey it is unlikely that participants would have felt the need to use the function for familiar trips. For the questionnaire data, participants responded to being asked 'Do you think that the distance covered / time taken to reach your destination will change / has changed as a result of your access to Navigation function?' This question is posed irrespective of the journey type and hence participants are likely to have considered a response based upon times when they actually used the function. In the case that the participants perception is assumed to be a real effect then we deduce that access to navigation can result in shorter and quicker journeys. This in turn reduces the amount of exposure to the road which is seen as beneficial in terms of safety.

Considering route choice, one conclusion is drawn from the questionnaire data where again the participants considered all journeys they undertook during the study. Here they reported a slight increase in the use of rural roads but no change in the use of highways. Rural roads are associated with a higher accident risk and hence this is potentially detrimental for safety. On the other hand, logged data indicated a slight increase in the use of city roads for comparable origin destination pairs.

Turning to distraction, the use of the navigation was shown, through detailed, experimental FOTs, to increase both the percentage of eyes off road time and the average length of glances away from the road and that these were related to the function use. The literature quantifies a doubling of the risk of accident involvement for glances in excess of 2 seconds. The trials highlighted very few such glances. However, this seems to be a very broad brush rule and the impact of glance behaviour requires more thought. Inherently any time looking away from the road (front / side / rear) for the primary task of driving or safety checks in mirrors could be considered as detrimental to safety but the extent of the impact has to be interpreted in the context also of the speed of travel and the driving environment. This has not been possible with the data collected in this study since a more naturalistic approach is required along with further video information describing the driving environment in relation to the glance behaviour.

<u>Speed information / speed alert</u>

There are no results that indicate a change in any of the safety indicators with the use of Speed Information / Speed alert. It is therefore concluded that, for the TeleFOT trials do not present any evidence to suggest that there is an impact upon safety.

<u>Traffic information</u>

The results of the analysis indicate that traffic information has an effect in the following areas; route choice and distance travelled.

Both the logged data and the questionnaire data indicate a slight increase in usage of rural roads which could be indicative of a switch to road types with a higher accident risk. On the converse, traffic information also showed through logged and questionnaire data to result in shorted journey durations which in turn represent a reduction in the exposure to accidents. It is not possible to quantify the extent of the positive and negative outcomes for safety in order to assess an overall impact.

Green driving

The results of the analysis indicate that traffic information has an effect in the following areas; route choice and distance travelled.

In relation to green driving around 5% of participants reported through the questionnaires that they perceived a very slight decrease in the use of highways with a corresponding increase in the use of rural roads. Logged data in the Finnish LFOT showed the function to increase the duration comparable journey durations. In terms of safety indicators the TeleFOT trials indicate a potential move towards roads with a higher accident risk and also to longer exposure on the road.

Limitations

Overall, the main limitation of the Safety Impact Assessment was that the usual metric for studying the 'safety' of a system did not apply. That is, within the TeleFOT FOTs there were no accidents and incidences reported therefore it is difficult to determine whether safety is really well and truly affected by After-market and Nomadic devices. Instead, inferences were used from metrics that are traditionally thought to affect safety although the relationship is not always clear or well–established. For example, both vehicle speed and long-term exposure of a vehicle to the risk of accident are documented throughout the research literature as factors that influence accident rates, but the relationship is such that the probability of an accident with increased speed or exposure is never 100%. Therefore some caution needs to be applied when interpreting the results of the Safety Impact Assessment. Other limitations of the results were also evident; the sample size used in some of the analysis relating to Safety was necessarily small. This particularly was the case for the analysis relating to research question 3 (SRQ-3 - "Does the device cause Distraction?") In order to address this question in its entirety, it would have been necessary to examine on a frame-by-frame basis all of the video data for all of the drivers at all of the test-sites collecting video data. However, with the available resources and project duration, it was only possible to analyse the video data for a sample of participants for which visual behaviour data was available. For these drivers, it was also only possible to select certain segments of the route driven. Whilst every effort was made to ensure that the segments (road junctions) that were chosen were both the most demanding in a visual and cognitive workload sense and where reliance on the Nomadic device was high (and hence whether the risk of Distraction was thought to be at its maximum), the fact remains that the sample size was small overall and nothing can be learned regarding the driving during other segments of the route. An initial attempt was made to overcome this dilemma by automating the visual data collection process (using eye-tacking equipment) but this was not successful as it became apparent that eye-tracking equipment, which works extremely well in carefully controlled laboratory environments does not work well in situations where the environment is very variable and changes rapidly (due to differential lighting).

Another limitation concerned research question 5 (SRQ-5 - “Is lane position affected?”) This is an important research question rightly included in the original Analysis Plan since it was hypothesised that the lateral and/or longitudinal positioning of the vehicle could be affected through using the device thereby increasing crash-risk. However, once the FOTs had commenced, it became apparent that there would be little available data that could satisfactorily identify whether a lane deviation had occurred, particularly within the Large-scale FOTs. Whilst the logged data was an excellent data source for examining certain characteristics of individual driving, the sampling rate for most test-sites was not sufficiently discrete to identify whether a lateral lane deviation had occurred. For longitudinal positioning, no logged data was available at all and therefore the analysis required to address the research question was reliant on subjective information. In this case, it is postulated that participants would firstly not be aware whether a lane-deviation had actually occurred and secondly would vary in their individual interpretations of the term “deviation” in a lane-positioning sense.

A general limitation of the analysis for Safety is that it is virtually impossible to extrapolate the results with statistical confidence to the European dimension given the small samples involved. However, this probably applies across other Impact Assessment domains as well.

7. CONCLUSIONS

The conclusions from the data analysis in respect of the impact of *single functions* supported aftermarket nomadic devices upon safety are as follows;

- Throughout the project there has been no measurable event (e.g. accidents or injuries) during the baseline and experimental conditions since these are relatively infrequent discreet events. Therefore it is impossible to quantify impacts on safety since cannot say injuries went up or accidents fell in relation to any function use.
- As a result we are left to infer the impact on safety associated with the use of the functions supported by the TeleFOT devices under assessment through specific safety research questions.
- These research questions are in themselves only generic indicators of the risk of accident and as such are not easily quantified.
- Therefore it is inappropriate to make predictions for the European dimension in relation to safety.
- According to Mobility RQ 11, the function that is perceived to have the greatest benefit for safety is speed alert but no logged data supported this.
- Traffic information showed a slight increase in the use of rural roads in the Swedish FOT which could represent a switch to road types with a higher accident risk but also resulted in shorter journey times which reduce the exposure to accidents. These two effects have apposing impacts on safety.
- Green driving indicated a potential increase in exposure and accident risk due to a shift in road type and longer journeys.
- The result on distraction is perhaps the most measurable in relation to safety since eyes off road time increased due to the function and the length of gazes also increased. This was the case for Navigation but not Green Driving.
- The HMI are different, GD is an image associated with a simple response required whereas navigation requires more cognitive processing to interpret the information.

- Although there were a few glances over 2 seconds, these occurred both to the navigation and equally to other areas of the visual scene. The 2 second guide is a rough rule of double risk which needs to be contextualised further with vehicle speed and complexity of road environment which influence crash risk.
- The devices used to provide the functions were limited; alternative devices with a diversity of HMI may provide wider ranging and perhaps different results.
- The market is evolving quickly and has even moved on during the life of the project. There is now more use of smart phone applications to provide functions, an example of a change in HMI.
- We have to ask the question ‘Is the HMI comparable to TeleFOT devices in relation to for example distraction?’
- Hence there is a need to keep evaluating how the changing HMI effects in particular driver distraction

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