TeleFOT

Field Operational Tests of Aftermarket and Nomadic Devices in Vehicles

Large Scale Collaborative Project

7th Framework Programme

INFSO-ICT 224067

Impacts on Environment – Results and Implications

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SEVENTH FRAMEWORK PROGRAMME

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LIST OF ABBREVIATIONS

ABBREVIATION	DESCRIPTION
ACC	Adaptive cruise control
ADAS	Advanced driver assistant systems
CAN	Controller area network
DFOT	Detailed field operational test
FCW	Forward collision warning
FOT	Field operational test
GDS	Green driving support
GPS	Global positioning system
ICT	Information and communication technology
LDW	Lane departure warning
LFOT	Large scale field operational test
LKA	Lane keeping assistant
NAV	Navigation
ND	Nomadic device
OD	Origin – destination
RQ	Research question
SA	Speed alert

SI	Speed limit information
THW	Time headway
TI	Traffic information
TTC	Time-to-collision
UU	User uptake

REVISION CHART AND HISTORY LOG

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EXECUTIVE SUMMARY

In this report the environmental impact assessment of the TeleFOT project is described and the final results are presented.

In the introduction the background of the TeleFOT project and some information about special terminologies used inside the project are given. Furthermore a short overview on former evaluations with regard to the influence of different driving parameters, like average speed, is provided and the overall purpose of the study is described.

Subsequent to the introduction the methodology of the Large Scale Field Operational Tests (LFOTs) and Detailed Field Operational Tests (DFOTs) are described briefly and the data which contributes to the analysis is listed. Following to the methodology description the different data types obtained during the test runs are specified.

After that the results of the research questions defined for the environmental impact assessment are presented. Therefore the hypotheses defined for each research question are given and the data is evaluated based on the available data. For this evaluation process the methodology, the numerical results and the statistical testing of the obtained results are described for each research question separately. In the environmental impact area the impacts are assessed upon

- Average speed
- Speed homogeneity
- Speed distribution
- Number of journeys
- Distance travelled
- Road type and choice of route
- Transport mode
- Fuel consumption
- Amount of CO_2 emissions

Following to the presentation of the results the implications for the environment of the four systems or functionalities respectively is pointed out. These implications are derived from the results between various test sites with several functions tested in the same research question and are therefore based upon the difference between the functionalities used in each test site and the difference in the obtained results.

Since there are no methods available with clear advice how to deal with bundles of functions, it was tried to separate each function and assess the impact of each function by its own.

The implications of the functions (if available) are summarised as follows:

Navigation

Average Speed	No significant change with function use
Speed homogeneity	No significant change with function use
Speed distribution	No significant change with function use
Number of journeys	No significant change with function use
Distance travelled	Perception of shorter journeys with function use, significant decrease in distance travelled
Road type and choice of route	Shift from higher class roads to lower class roads (e. g. urban streets and unpaved roads)
Transport mode	No significant change with function use
Fuel consumption	No significant change with function use
Amount of CO_2 emissions	No significant change with function use

Traffic Information

Average Speed	Increase of average speed on urban roads with function use
Speed homogeneity	No significant change with function use
Speed distribution	No significant change with function use
Number of journeys	No significant change with function use
Distance travelled	No significant change with function use
Road type and choice of route	Shift from interurban and rural roads to highways
Transport mode	No significant change with function use
Fuel consumption	No information available
Amount of CO2 emissions	No information available

Speed limit information / speed alert

Average Speed	No significant change with function use
Speed homogeneity	No significant change with function use
Speed distribution	No significant change with function use
Number of journeys	No significant change with function use
Distance travelled	No significant change with function use
Road type and choice of route	No significant change with function use
Transport mode	No significant change with function use
Fuel consumption	No significant change with function use
Amount of CO2 emissions	No significant change with function use

Green Driving

Average Speed	No significant change with function use
Speed homogeneity	No significant change with function use
Speed distribution	The variance of the speed distribution is smaller
Number of journeys	No significant change with function use
Distance travelled	Significant increase in distance travelled
Road type and choice of route	No significant change with function use
Transport mode	No significant change with function use
Fuel consumption	Significant decrease in fuel consumption
Amount of CO2 emissions	Significant decrease in CO_2 emissions

With regard to the above mentioned implications to environment, the following conclusions can be drawn:

- Navigation support indicates a positive and a neutral or a possible negative impact on the environment. The positive outcome is that shorter journey lengths and durations have of course a positive contribution to the environment. A change from higher class roads (motorways, rural roads) to lower class roads (urban streets, unpaved roads) can have a positive, a neutral or a negative influence. This is dependent on the environmental and traffic conditions on the roads. Changing from a crowded high class road onto a lower class road with a low traffic density and nearly the same distance to destination is certainly a positive outcome whereas changing from the same high class road onto a lower class road with a distinctly longer route to the destination might contradict fuel saving, but this is very situation-dependent.
- Traffic information could show its potential regarding the environment in two aspects. A significant increase in average speed as well as the change from lower class roads to higher class roads can lead to a decrease of environmental load. Both aspects are more or less closely linked. When the traffic participants change

from crowded lower class roads (rural roads) onto higher class roads (highways), the average velocity will inevitably increase and while driving at a constant velocity on rural roads the engine works near its optimum. This contributes to the environment.

- Speed limit information/speed alert could not show any potential to contribute to fuel saving or other environment related factors. However, these functionalities are more safety functions than energy saving functions and therewith this outcome is not astonishing.
- Green driving support has primarily been developed to lead to a fuel saving while driving. This capability could be shown in several FOTs during the project. The green driving support could save four per cent fuel in average. Therewith it also has the opportunity to reduce CO_2 emissions since emissions are directly linked to fuel consumption. An additional outcome is a smoother velocity profile since the variance of the speed distribution was smaller. This also contributes to fuel saving. In one case, it could be seen that the distance travelled has increased. This must also be reviewed regarding the fuel consumption. If the route is longer, but the absolute fuel consumption is less than without the system, it is still a positive result with regard to the environment.

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 1st June, 2008, TeleFOT aims to test the impacts of driver support functions on the driving task with large fleets of test drivers in real-life driving conditions. In particular, TeleFOT assesses via Field Operational Tests 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. In order to measure the impacts, core research questions and hypotheses were developed for each assessment area that also take into account the functionality of the devices specifically under consideration in TeleFOT. Each analysis plan deliverable details the proposed approach to be followed but does not give analysis outputs.

1.2. Terminology

In this report a before-after study design was used. The before phase is used as baseline. The after phase is called “treatment” although the participants did not use the functions for all journeys. Nevertheless, the functions were available in the treatment condition and the subjects could choose when to use them.

1.3. Summary of earlier findings

Since the late part of the 20th century the carbon output from road transport has become a significant issue for governments, car manufacturers and consumers. The most recent figures released by the European Union in 2011 showed that transport (including road, rail, air and shipping) was responsible for 19% of total greenhouse gas emissions, with road transport contributing 82% of this share (Eurostat, 2011). Greenhouse gases emissions as a result of domestic transport increased by 26% between 1990 and 2004, despite other sectors such as energy supply, industry and agriculture showing a decrease in emissions (EEA, 2007).

However in recent years a trend has been seen within the EU for road transport emissions to actually be reducing since 2007 by 2.9% (EEA, 2010). This may be due to a number of factors including socioeconomic influences such as the increase in fuel prices or pressures on personal income. In Europe there has been a shift in consumer trends for more economical personal transport, with smaller, more efficient cars now achieving a greater market share. Additional aspects influencing this may include engineering solutions being developed by vehicle manufacturers such as hybrid powertrains, low carbon vehicles and more efficient internal combustion engines.

Another way which the environmental impact of driving can be reduced is by adopting a fuel efficient (aka eco-driving) style, which can lead to fuel savings of up to 15%. In a recent review (Young et al., 2011) the effects that smart driving technologies have on driving performance was described as follows: “When drivers are asked to drive more efficiently, they generally interpret this as to drive slower”. Indeed, Anable and Bristow (2007) estimated that enforcing the 70 mph (≈113 km/h) speed limit on dual carriageways and motorways in the UK could save around one mega-tonne of carbon per year. Reducing the speed limit to 60 mph (≈97 km/h) would almost double the saving to 1.88 mega-tonnes. Generally, though, it is thought that fuel efficiency is at its maximum between 60 and 80 km/h (cp. Figure 1), as this optimises the trade-off between overcoming rolling road resistance and increasing wind resistance (Andre, Hammarstrom, 2000; Haworth, Symmons, 2001; El-Shawarby et al., 2005).

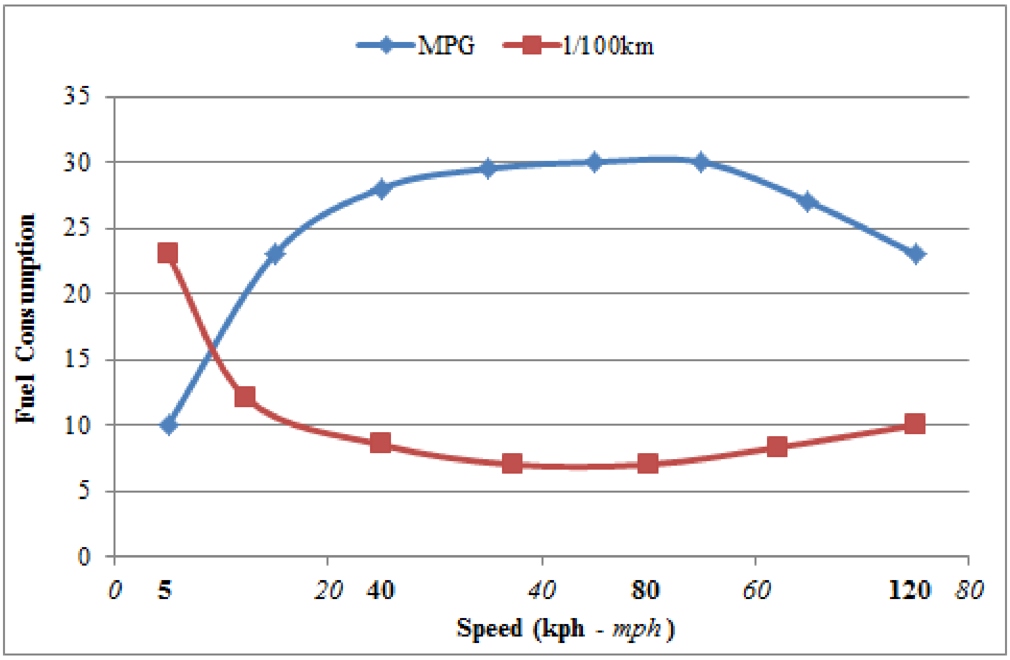

Figure 1: The relationship between vehicle cruising speed and fuel economy

Young and colleagues continue: "Clearly, then, simply reducing speed is not the only – nor is it the optimal – strategy for eco-driving, especially considering the implications for journey time. In fact, there are several factors other than speed which can influence both fuel consumption and emissions. Data from a study by Ericsson (2001) suggests the focus should be on avoiding heavy acceleration, large power demands and high engine speeds. Similarly, Johansson et al. (2003) found certain characteristics of driving behaviour that were significantly correlated with good fuel economy, such as avoiding unnecessary stops, maintaining low deceleration levels, minimising the use of 1st and 2nd gears, increasing the use of 5th gear, and block changing gears where possible." (Young et al. (2011)).

The effect of vehicle speed on emissions rates (e.g. particulate matter smaller than 10 micrometres (PM_{10}), nitrogen dioxide (NO_x), non-methane hydrocarbons (NMHC) and carbon monoxide (CO) follows similar trends to that of CO_2 and fuel economy. Figure 2 shows how emission rates remain elevated until approximately 40 km/h cruising speed and then stay comparatively low until around 120 km/h where modest increases are then observed.

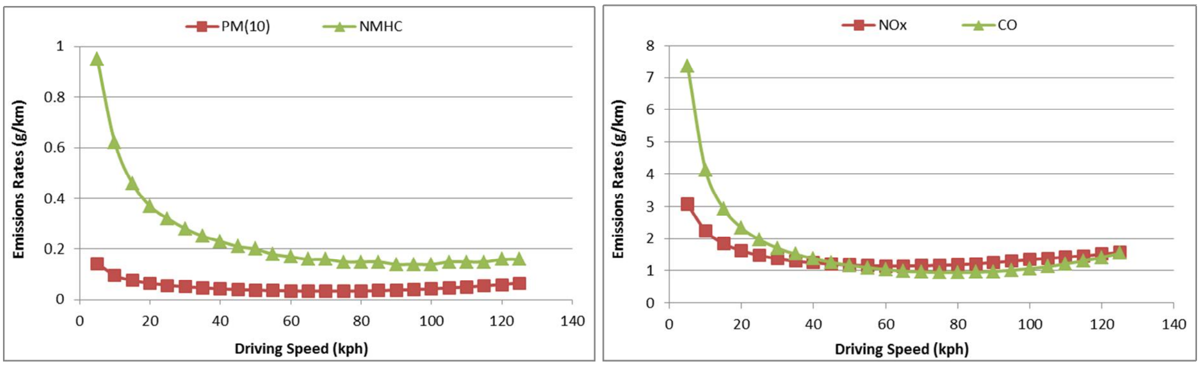

Figure 2: The relationship between vehicle cruising speed and emissions rates. Graph 1 shows PM and NMHC; Graph 2 NO_x and CO. (Highway Agency (2005))

Other studies have shown that emission rates are more directly affected by 'aggressive' driving than average speed. Johansson et al. (2003) showed that eco-driving training decreased CO_2 emissions by 10.9% compared to those who had not been trained. The study also suggests a relationship between the percentage of time spent at more than half throttle and higher emissions of hydrocarbons (HC) and carbon monoxide (CO), and between higher engine speeds and NO_x emissions. Aggressive accelerations, on the other hand, have been shown to increase HC and CO emissions by 629% and 470% respectively, compared to mild accelerations (El-Shawarby et al., 2005). Surprisingly, no differences in CO_2 were observed, and NO_x actually decreased by 65% in the same comparison. However, this finding has not been supported elsewhere. De Vlieger (1997) observed that aggressive driving tripled CO emissions, and doubled output of HC and NO_x. Conversely, CO and HC were reduced compared to normal driving when drivers drove economically, although no difference was observed with NO_x. These results were supported by De Vlieger et al. (2000) who showed that aggressive driving in a petrol driven 1.4 Renault Megane increased CO emissions by a factor of eight, HC up to 400% and NO_x by 150%. More equivocal results were found for diesel cars, with varied or non-significant changes to the CO and HC emissions under aggressive driving, although emissions of NO_x did significantly increase by between 50% and 200%. In addition to driving style, De Vlieger (1997) noted that driving a short journey from a cold start resulted in significantly higher CO and HO emissions compared to a hot start.

This review illustrates that the effect of average speed on emissions is multi-dimensional, namely a lower average speed on high speed roads could be considered to be beneficial to the environment. Whereas the opposite may be considered true for low speeds roads, with Figure 1 and Figure 2 showing improvements in fuel consumption and emissions as speed increases up to approximately 40 km/h. Speed related factors which may have a greater influence on reducing environmental impact compared to simply assessing the average speed of an entire journey are issues such as exceeding the speed limit on high speed roads, and minimising stops to facilitate an increase in speed consistency, aka a smoother speed profile, in lower speed conditions.

A smoother speed profile can be measured by means of speed distribution and speed variances. Therefore research questions two and three were developed to find out if the TeleFOT function can contribute to change the driving behaviour to a smoother speed profile.

Regarding environment the easiest way to save fuel and to avoid emissions is to reduce the trips by car. The research question: “Is number of journeys affected?” tries to answer if any of the functions help to avoid unnecessary journeys. Another factor can be instead of not driving at all to change the travel mode, e. g. riding the bike instead of driving by car.

1.4. Purpose of the study

The purpose of this study is to determine the impact of nomadic and aftermarket devices on different impact areas like safety, efficiency, mobility, environment and on user-uptake. The study consists of various Field Operational Tests (FOTs) that have been conducted in different test sites and with changing systems and functionalities. The FOTs were designed to evaluate these different systems and functionalities under changing conditions and with a huge amount of users. Therewith it is possible to evaluate occuring effects in general with the help of large scale FOTs and in case of any appearing characteristics to utilize these effects more in detail inside the detailed FOTs.

Inside the project, objective data logged during the test runs and subjective data collected via questionanaires have been evaluated to determine the impact of the use of nomadic and aftermarket devices on various users.

In this part of the study the environmental impact of the use of nomadic and aftermarket devices and their different implemented functionalities is about to be determined. Therefore several different research questions, like “Is the average speed affected?” or “Is the number of journeys affected?” have been determined in advance with corresponding hypotheses, like “There is an increase / decrease in average speed.”, that are describing the expected impact of the systems directly or indirectly on the environment.

The data has been analysed in different ways with regards to these predefined hypotheses and the results of this evaluation process is presented in this report.

The objective of this deliverable is to provide the results achieved during the test runs of the TeleFOT project with regard to the environmental impact of nomadic and aftermarket devices. The environmental impact can be assessed based upon the change in mileage (number and length of journeys), fuel consumption and therewith CO_2 emissions and the emission of other pollutants.

2. METHOD

In this chapter the methodology of large scale field operational tests (LFOTs) and detailed field operational tests (DFOTs) in the TeleFOT project with regard to environment is decribed briefly. Therefore the structure of those FOTs is presented in a first step and then the data which is gathered during these FOTs and which is available to answer the research questions is described. A short summary of each FOT with the tested functions can be found in Annex I.

2.1. Large Scale FOTs

In total 11 LFOTs have been executed in the course of TeleFOT. The experimental setup of all LFOTs is described in Pagle et al. (2012). Those LFOTs which contributed to the analysis of the research questions of the environment impact area are listed in Table 1.

FOT	Function / s	Data Type	Number of participants	Total driving km
SWE-LFOT1	SA, GDS	Questionnaire	54	109177
SWE-LFOT2	NAV, GDS, TI	Logger, Travel diary, Questionnaire	96	653165
SWE-LFOT4	TI	Logger, Questionnaire	554	428092
FIN-LFOT2	GDS, TI, SI/SA	Logger, Travel diary, Questionnaire	140	344000
IT-LFOT	NAV, SI/SA	Logger, Travel diary, Questionnaire	168	n/a
ES-LFOT1	NAV, SI/SA	Logger, Travel diary, Questionnaire	120	n/a
ES-LFOT2	NAV, GDS	Logger	132	3249529
GR-LFOT 1-4	NAV, SI, TI, SA	Logger, Travel diary, Questionnaire	148	806776
UK-LFOT	NAV, SI/SA	Logger, Travel diary, Questionnaire	80	~300000

Table 1: LFOT data which contributes to environment impact assessment

By summing up the driven kilometres (if they are available), the huge amount of 5,890,000 kilometres come up which contributed to the analysis of the environment impact assessment. Additional to the logged data, travel diary data as well as questionnaire data could be gathered during the LFOTs and conducive to the analysis.

2.2. Detailed FOTs

The main differences between LFOTs and DFOTs are the higher equipped test vehicles to gather more beneficial data, the lower amount of test subjects and a shorter duration. The detailed field operational tests are controlled experiments with some boundary conditions which do not exist in LFOTs, for instance the subjects have to drive a pre-defined route for several times with different driving aids. The advantage of those controlled experiments is the higher equipped vehicle which enables to gather much more data during the test runs, e. g. vehicle dynamic data from the vehicle's CAN bus or even video data. Especially for the environment impact assessment, those DFOTs delivered important data to analyse some of the research questions. Those DFOTs which contributes to the environment impact assessment are mentioned in Table 2.

FOT	Function / s	Data Type	Number of participants	Total driving km
UK-DFOT2	GDS, FCW, LDW	Logger, Questionnaire	40	4910
UK-DFOT3	FCW, LDW	Logger	23	1980
GER-DFOT	NAV, SI/SA, ACC, FCW, LKA	Logger	9	11400
ES-DFOT1	SI/SA	Logger	32	500
IT-DFOT	GDS, (NAV, TI)	Logger, Questionnaire	48	907
FIN-DFOT (TeleBUS)	GDS	Logger	143	475000

Table 2: DFOT data which contributes to environment impact assessment

All information regarding those DFOTs can be found in Koskinen et al. (2012).

2.3. Data

Within the different experimental designs of LFOTs and DFOTs several types of data were gathered. There are objective data (logger data), semi-objective data like travel diary data and subjective data like questionnaire data available for the analysis of the research questions (see Annex II for Statement of principles regarding data-sharing following TeleFOT).

2.3.1. Logger data

All vehicles were equipped with a GPS logger which recorded at least the GPS position with a frequency of 1 Hz. The availability of additional data varied a lot throughout the test sites because several different loggers were used. Beside the GPS loggers, some nomadic devices had the possibility to log also information during the drives, for instance velocity, number of satellites or button presses which proves the interaction between the driver and the device.

As already mentioned in 2.2, most of the DFOTs were explicitly better equipped. Beside a vehicle CAN bus logger which records e. g. signals of velocity, acceleration, yaw rate, steering wheel angle and many more, additional sensors came into operation. With radar sensors in the front, the distance to the preceding vehicle and its velocity could be measured and therewith performance indicators like time-to-collision (TTC) or time headway (THW) could be calculated. For the environment impact assessment a fuel gauge was necessary which was also only available in some DFOTs. Video data completed the equipment of some vehicles in the DFOT. Figure 3 shows a picture of one camera which observes the traffic situation ahead.

Figure 3: View of one camera observing the traffic ahead

2.3.2. Travel diary data

Travel diaries were filled out in paper format once a day. They contain information like origin, destination, start time, end time, trip length, mode of travel and purpose. Travel diaries were initially developed for the mobility impact assessment, but in the course of the TeleFOT project, it became clear that they have the potential to answer also research questions in the environment impact area. Especially the mode of travel cannot be logged anyhow else, so that this is a valuable instrument to notice a change in mode of travel.

2.3.3. Questionnaire data

Several questionnaires have been created beforehand of the FOTs. A background questionnaire collects information regarding age, gender, driving style etc. During the FOTs three or four user uptake questionnaires have been distributed to the subject. One pre-questionnaire before the start of the FOT, one or two during-questionnaires (dependent on the length of the FOT) and a post-questionnaire after finishing the FOT should be filled out by the subjects. They collect information regarding the perceived potential of the different functions to assist the driver while driving, for instance.

3. IMPACTS

3.1. Average speed

In this chapter the first research question of the environmental impact assessment Env-RQ1: "Is average speed affected?" is addressed. With this research question the hypothesis H1.1: "There is an increase/ decrease in average speed" is about to be answered with the help of the data logged during the test runs.

3.1.1. Data used

At first the data used for the evaluation is described in detail. Therefore the different data types and specifics of the used data are described in detail.

3.1.1.1 Data type

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 4).

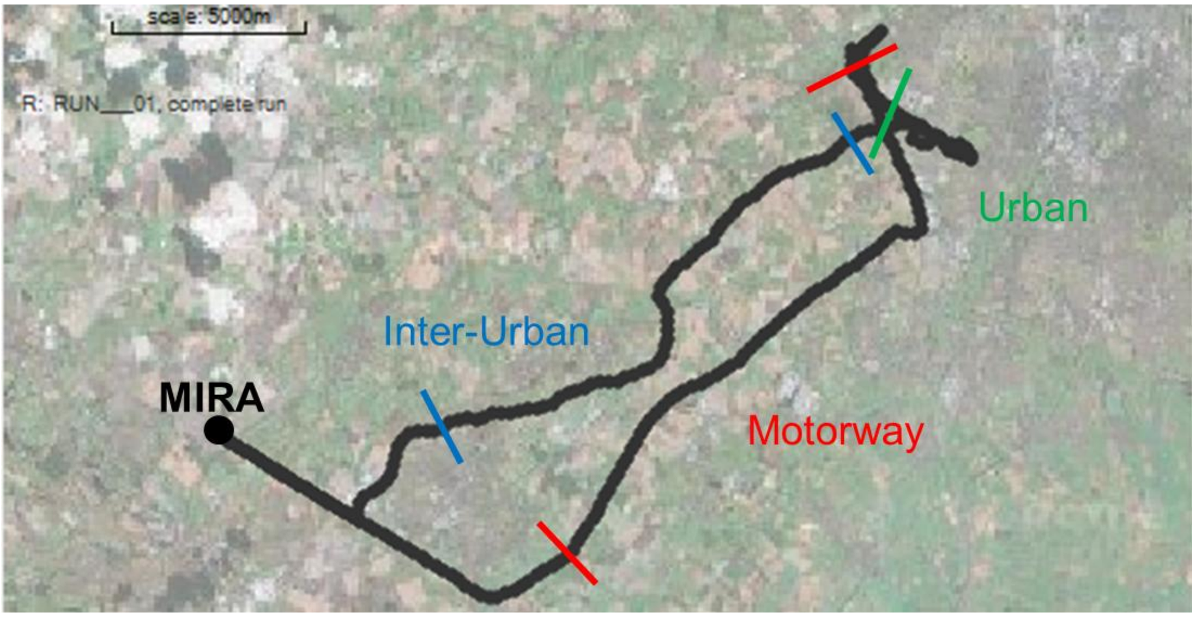

Figure 4: Driving route selected for UK DFOT 2

With UK DOFT 2 the motorway (aka freeway, autobahn etc.) 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 kph), 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. For further details on the FOTs please refer to please refer to Koskinen et al. (2012).

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.

Functions and FOTs evaluated are shown in Table 3.

FOT	Function / s	Data Type	Number of participants	Total driving km
UK-DFOT2	GDS, FCW, LDW	Logger	40	4910
UK-DFOT3	FCW, LDW	Logger	23	1980
GER-DFOT	SI/SA	Logger	9	11400
SWE-LFOT2	NAV, GDS, TI	Logger	96	653165
SWE-LFOT4	TI	Logger	554	428092
FIN-LFOT	GDS, TI, SI/SA	Logger	140	344000

Table 3: Data used for the analysis of EnvRQ1

3.1.1.2 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: 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: 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.

3.1.1.3 Anticipated effect of functions to be tested

Overall, It was anticipated that ADAS was unlikely to have any effect on average speed. Therefore the German DFOT tested a combination of factors to see what if any factors associated with SL/SA would lead to a reduction in average speed. However, as a DFOT methodology was used, it was anticipated that the particpants were more likely to keep to the speed limits than was the case within the LFOTs where the driving was more 'naturalistic'. This implied a limited effect for SI/SA. It was anticipated that ACC and CC could lead to an improvement in fuel consumption but that it would depend on the driver. It was expected that a fuel efficient driver adopting a fixed throttle, variable speed technique (speed up down hills, slow down up hills) or pulse and glide would probably use more fuel when using CC. However, it was also expected that the average driver would probably save fuel (given the propensity to feather the throttle and also speed up unintentionally, or intentionally when they get closer to home). So, ADAS was only one were small part of one DFOT and was evaluated in conjunction with other features, and worthy of analysis if to examine whether it has the predicted effect or not.

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 Support (GDS) 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). However, as reviewed in the introduction average speed with respect to environmental impacts are entirely different. As we can see in Figure 1 and Figure 2 an increase in average speed with urban driving could be considered more environmentally friendly as fuel consumption and emissions decrease rapidly from 5 to 25 km/h. Whereas keeping speed as close to 90 km/h on high speeds roads also leads to dramatic increase in efficiency.

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.

3.1.1.4 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 GDS 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.

3.1.1.5 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.

3.1.1.6 Statistical Testing

The "unit of analysis" was average speed. All journeys were compared the same journey pre and post intervention, using the 'Most common legs' data. In the LFOTs each participant probably had more than one common journey which was included in the analysis, but the common journeys were paired for the statistical analysis. It may have been posible to break individual journeys down by participants to examine the situation for individuals, however overall the TeleFOT project was more interested in the "bigger picture" rather than for individuals. Therefore, common journeys were paired (independently of who completed them) pre and post intervention.

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.

3.1.2. Results

UK DFOT 2: Results showed no significant difference in average speed between the control and intervention (Foot-LITE; Eco (GDS) and Safe (FCW & LDW) driving in-vehicle feedback) conditions for either the journey as a whole or for the individual road sections (MW = Motorway; URB = Urban; INT = Inter-Urban; Figure 5).

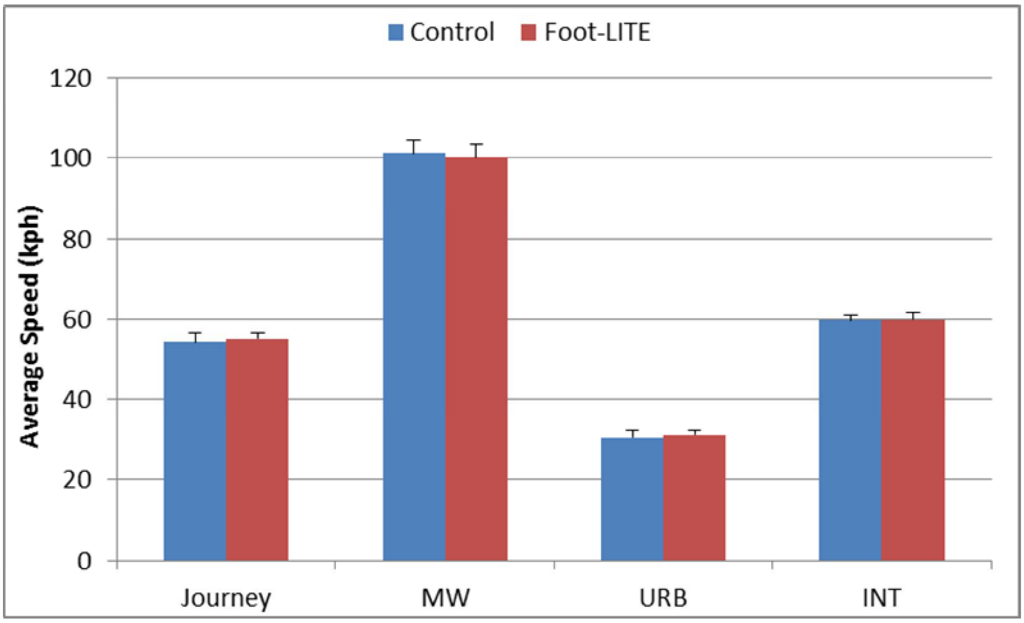

Figure 5: Average Speed data from UK DFOT 2. Error bars represent the standard deviation of the mean data

UK DFOT 3: Again results show no significant difference in average speed when using the Mobileye ADAS system (FCW and LDW) for the three different road types (Figure 6).

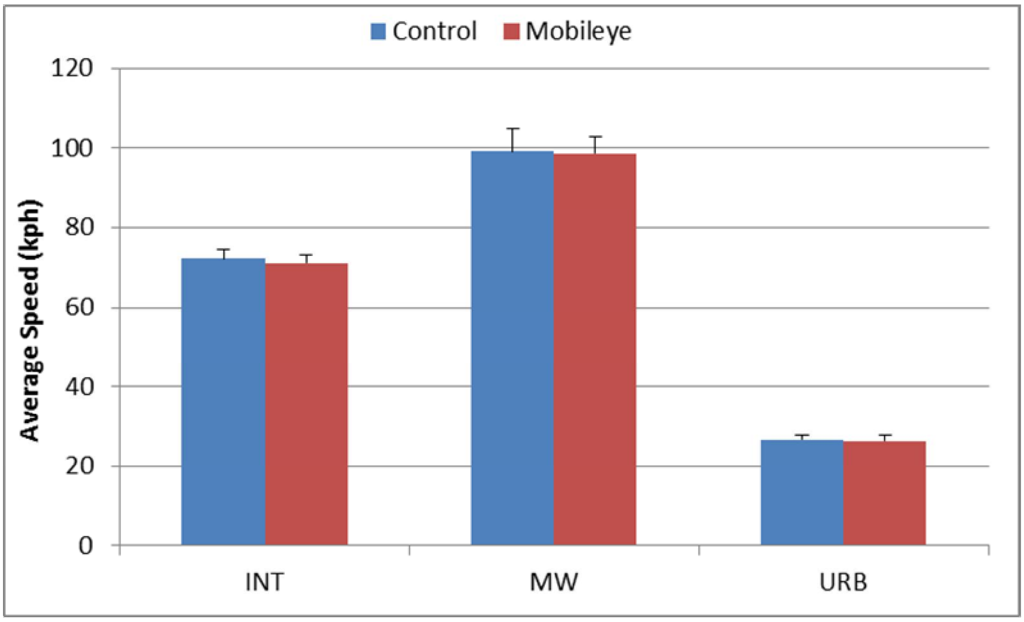

Figure 6: Average speed data from UK DFOT 3. Error bars represent the standard deviation of the mean data

GER DFOT 1: Results from the German DFOT also suggest no significant difference in average speed for the four driving scenarios analysed when using a combination of ADAS and speed information and speed alert systems (Figure 7). The x-axis represents the four different driving routes adopted in this FOT.

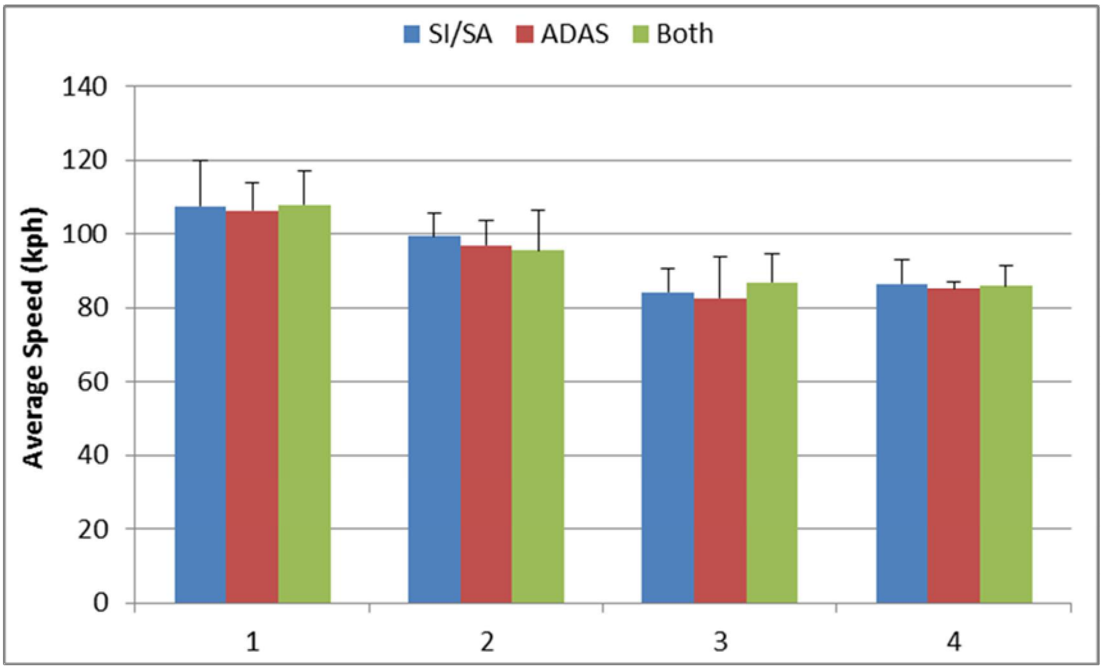

Figure 7: Average speed data from GER DFOT 1. Error bars represent the standard deviation of the mean data

SWE LFOT 2: Results from the first of the LFOTs presented here shows a significant increase in the average speed for the entire journey (Ave_Vel) as observed when driving in the intervention phase compared to control (Figure 8). With this LFOT drivers were using navigation support with the added features of TI and GDS. This increase in average speed was from 37.4 km/h to 38.6 km/h from the control to intervention phase respectively, an increase of 1.2 km/h or 3.2%. Although this difference is only a modest increase the large data sets revealed this difference was significant. Average speed in what was classified as ‘Urban’ roads (Ave_Urban) was also significantly greater in the intervention period compared to the control; this difference was slightly larger with average speeds increasing from 31.3 km/h to 33.4 km/h respectively, an increase of 2.1 km/h or 6.7%. No difference was observed when driving was categorised as being through an ‘Intersection’ (Ave_Inter).

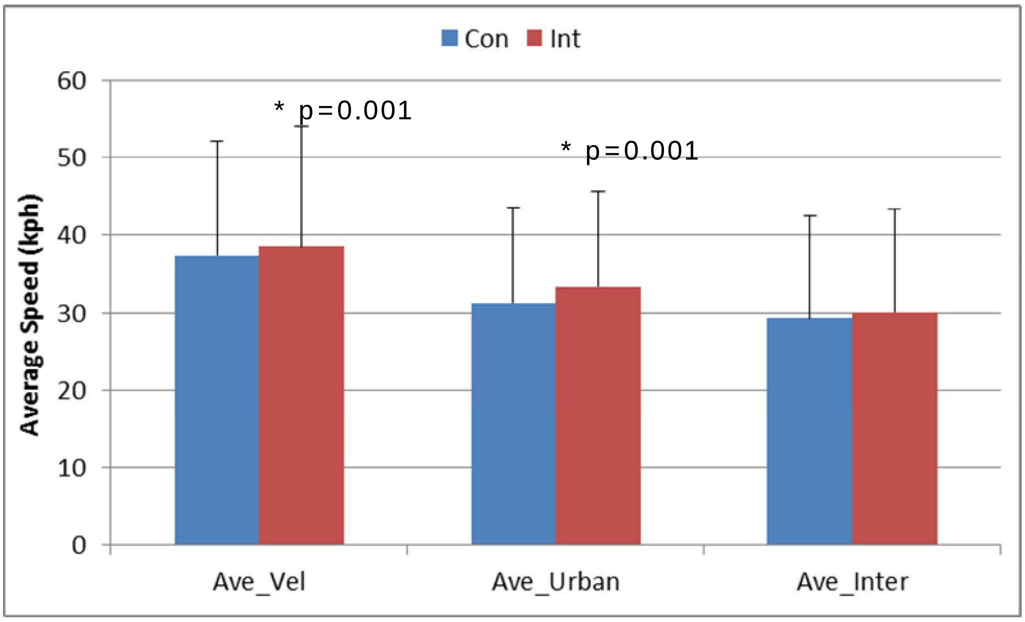

Figure 8: Average speed data from SWE LFOT 2. Error bars represent the standard deviation of the mean data

SWE LFOT 4: Results from SWE LFOT 4 show no difference in average speed data when using the TI and route guidance app when considering the journey (leg) as a whole or even when driving through intersections (Figure 9). However a significant increase of 4.2% in average speed was observed when driving on roads classified as Urban.

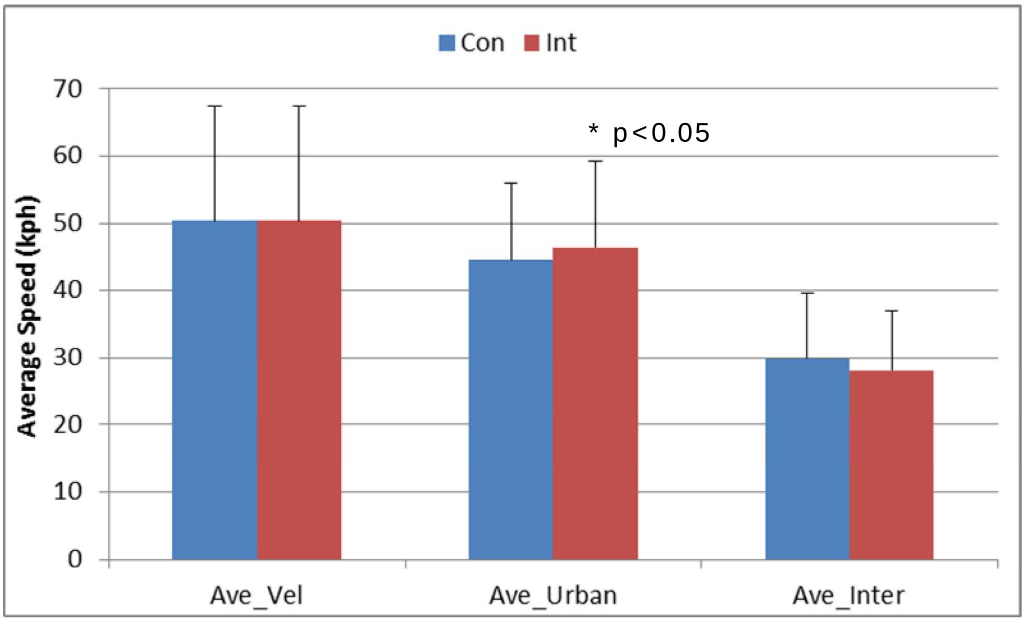

Figure 9: Average speed data from SWE LFOT 4. Error bars represent the standard deviation of the mean data

FIN LFOT 2: Results from the Finnish LFOT show that average speed did not differ between the control (in this FOT the control period was driving with TI and TI+SI) and intervention phases (in this case driving with TI, TI+GDS and TI+GDS+SA; Figure 10).

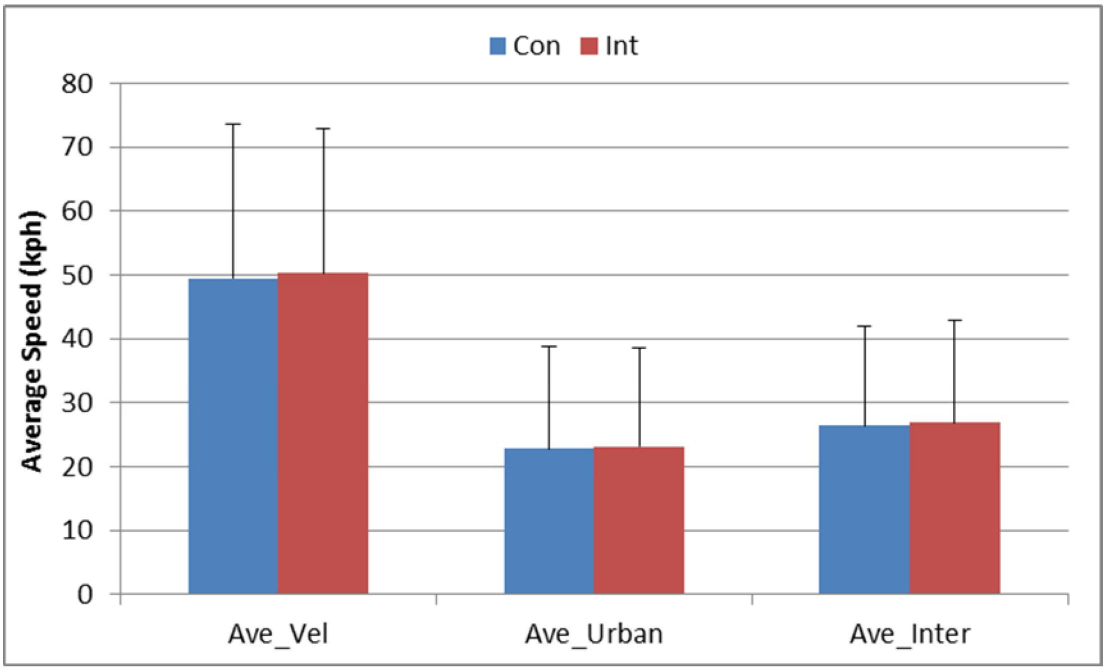

Figure 10: Average speed data from FIN LFOT 2. Error bars represent the standard deviation of the mean data

3.1.2.1 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. 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.

3.1.2.2 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.

3.1.2.3 Discussion and Conclusions from the Data Analysis

Results from UK DFOT 2 (Figure 5) 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 support (GDS) 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). This FOT showed that increases in fuel efficiency of 4.1% (discussed in EnvRQs 8 and 9) can be achieved with no impact on journey time or average speed.

Both SWE LFOT 2 and FIN LFOT 2 (Figure 8 and Figure 10 respectively) also utilised GDS 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 GDS 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 GDS functions, it can be seen that SWE LFOT 2 showed a significant increase in average speed when driving on urban road types (Figure 8). Results from UK DFOT 2 also suggest a non-significant increase in average speed when driving with the GDS system in the urban scenario of 2% compared to the control condition (Figure 5). 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 (and the subsequent use of inefficient 1st and 2nd gears (Johansson et al., 2003)) but also to maintain a smoother speed profile which can lead to increases in overall speed. This is supported by an early study conducted by Evans (1979) who when instructing drivers to minimise fuel consumption saw two distinct strategies being adopted – reducing speed and accelerations, and minimising stops (which often result in increased acceleration). Fuel consumption savings were different for each strategy: 6.4% for the 'speed' strategy, and 13.9% for the 'stops' subgroup. Furthermore, trip times increased by 8.2% for the speed subgroup but only 1.5% for the stops subgroups. Results from the literature and this analysis suggest that green driving does not have to lead to a reduction in average speed in order to increase fuel efficiency, a factor which is a common misconception regarding adopting an eco-driving style.

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 (Figure 7) 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 (Figure 5 and Figure 6) 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 (Figure 7). FIN LFOT 2 also showed no difference in average speed for the journey when using SI in combination with GDS and TI (Figure 10). 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. Given this it can be suggested SI/SA may have a greater effect on maximum speed, occurrences of over-speeding and speed distributions rather than 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 GDS; 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 (Figure 8) 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 GDS 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 (Figure 9) 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 (Figure 10) 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 EnvRQ1 '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 (GDS, 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 GDS 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.

3.2. Speed homogenity

In this chapter the second research question of the environmental impact assessment, Env-RQ2: "Is speed homogenity affected?" is addressed. With this research question the hypothesis H2.1: "There are changes in speed homogeneity." is about to be answered with the help of the data logged during the test runs.

3.2.1. Data used

In this chapter the data used for the evaluation is described in detail. Therefore the different data types and specifics of the used data are given in detail.

3.2.1.1 Data types

In Table 4 the different functions tested in the given FOTs are listed. Beneath the functions the corresponding data type and the number of subjects participating in the FOTs are given.

FOT	Function / s	Data Type	Number of participants	Total driving km
UK-DFOT2	GDS	Logged	40	4800
ES-DFOT1	NAV, SI/SA	Logged	32	500

Table 4: Data used for the analysis of EnvRQ2

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

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 logged all data or it crashed during the test. And it was detected that subject 6 had considerable less data compared to the other participants so that data were excluded too.

In ES-DFOT1 data was not logged by the device for one participant.

Also, some filters were applied to this data, in order to obtain reliable conclusions. Firstly, as this hypothesis deals with means data where speed value was zero were excluded as well as values where speed was higher than 200 km/h.

3.2.1.3 Anticipated effect of function to be tested

The anticipated effects of most of the functions regarding the speed homogeneity are generally unknown. However, it is expected that when using a nomadic device with green driving support (GDS) as its primary function that will contribute to homogenize the speed distribution.

3.2.1.4 Anticipated influence of combinations of functions

Within UK-DFOT2 data, only green driving support is analysed, so there is not a combination of functions and hence any effect seen in this data is due to the green driving support.

From ES-DFOT1 combination of functions the results are uncertain.

3.2.1.5 Data Selection, filtering and post processing for analysis

Data were selected from UK-DFOT2 and ES-DFOT1 based upon the following criteria

Logged data

- Only selected participants whose full set of data where acquired (both conditions baseline/Foot-lite).
- Speed data between 0.1 km/h-200 km/h

3.2.1.6 Statistical Testing

Non parametric test, specifically Mann Whitney test, was used to test distribution homogeneity between data in baseline condition and treatment condition of the DFOTs.

H0: Speed distribution is not affected against the alternative hypothesis

H1: Speed distribution is affected.

3.2.2. Results

3.2.2.1 UK-DFOT2

Data from UK-DFOT2 showed a significant change in the speed distribution between both conditions (baseline and Foot-LITE device). The distributions are not homogenous among both conditions.

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of Vspe_GPS_cat is the same across categories of Condition.	Independent-Samples Mann-Whitney U Test	,000	Reject the null hypothesis.
2	The distribution of Vspe_cat is the same across categories of Condition.	Independent-Samples Mann-Whitney U Test	,000	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Figure 11: Hypothesis Test Summary

This result could be influenced by the large amount of data analysed (1.5M) and the sensitivity of the Mann-Whitney test.

3.2.2.2 ES-DFOT1

The result of the ES-DFOT1 data is similar to the UK-DFOT2. The two systems data showed a significant change in the speed distribution between both conditions (baseline and treatment with NAV+SI/SA). However there is no difference in average speed among the two conditions.

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of Speed is the same across categories of Condition.	Independent-Samples Mann-Whitney U Test	,000	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Figure 12: Hypothesis Test Summary

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of Speed is the same across categories of Condition.	Independent-Samples Mann-Whitney U Test	,000	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Figure 13: Hypothesis Test Summary

3.2.2.3 Discussion and Conclusions from the Data Analysis

The speed homogeneity of those two test sites analysed showed differences. But, even that the speed distribution using the tested functions is not homogeneous to the baseline speed distribution, there is no differences in the mean. This can be explained with an example:

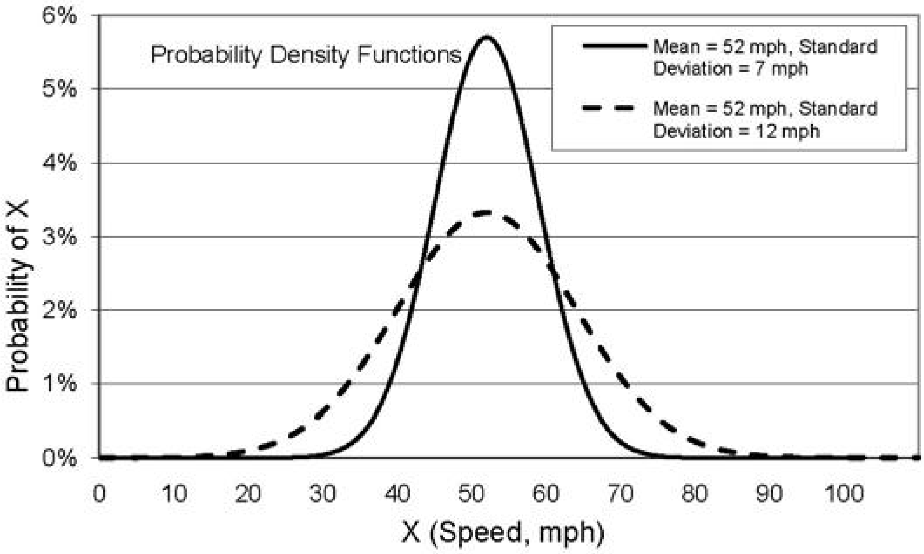

Figure 14: Example of two distributions with the same mean, but not being homogenous

Both distributions have the same mean but different standard deviation which makes them not being homogeneous.

3.3. Speed distribution

In this chapter the third research question of the environmental impact assessment, Env-RQ3: "Is speed distribution affected?" is addressed. With this research question the hypothesis H3.1: "There is a/is no change in speed distribution" is about to be answered with the help of the data logged during the test runs.

3.3.1. Data used

In this chapter the data used for the evaluation is described in detail. Therefore the different data types and specifics of the used data are given in detail.

3.3.1.1 Data types

In Table 5 the different functions tested in the given FOTs are listed. Beneath the functions the corresponding Data type and the number of subjects participating in the FOTs are given.

FOT	Function / s	Data Type	Number of participants	Total driving km
UK-DFOT2	GDS	Logged	40	4910
ES-DFOT1	SI/SA	Logged	32	500
SWE-LFOT2	NAV, GDS, TI	Logged	96	653165
FIN-LFOT	GDS, TI, SI/SA	Logged	140	344000
IT-LFOT	NAV, SI/SA	Logged	168	n/a
ES-LFOT1	NAV, SI/SA	Logged	120	n/a

Table 5: Data used for the analysis of EnvRQ3

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

The UK-DFOT2 used the smart driving system Foot-LITE which 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 logged all data or sometimes it crashed during the test and it was detected that one subject had considerable less data compared to the other participants so that this data were excluded, too.

In ES-DFOT1 data was not registered by the device for one participant.

Also, some filters were applied to this data, in order to obtain reliable conclusions in DFOTs and LFOTs. Firstly, as this hypothesis deals with means data where speed value was zero were excluded as well as values where speed was higher than 200 km/h.

SWE-LFOT2: Only common trips were analysed in this analysis. This was defined as a journey which was completed three or more times in both the baseline and intervention periods. This resulted in a total of 6415 journeys being analysed.

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

IT-LFOT: Only common trips were analysed in this analysis. This was defined as a journey which was completed three or more times in both the baseline and intervention periods. This resulted in a total of 73 journeys being analysed.

ES-LFOT1: Only common trips were analysed in this analysis. This was defined as a journey which was completed three or more times in both the baseline and intervention periods. This resulted in a total of 1166 journeys being analysed.

3.3.1.3 Anticipated effect of function to be tested

The anticipated effects of most of the functions regarding the speed distribution or the speed homogeneity are generally unknown. However, it is expected that when using a ND with green driving support (GDS) 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 because this function contribute to homogenise speed.

3.3.1.4 Anticipated influence of combinations of functions

Within UK-DFOT2 data, only GDS is analysed, so there is not a combination of functions and hence any effect seen in this data is due to the green driving support.
When green driving support is combined with another function the effect expected will be a speed distribution more homogeneous. However, for the other combinations of functions the anticipated effect is unknown.

3.3.1.5 Data selection, filtering and post processing for analysis

Data were selected from UK-DFOT2 and ES-DFOT1 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 - 200 km/h

Whereas LFOT data were selected following the next procedure

- Select the common journeys from the common legs excel file of each country
- Checked that a journey was completed three or more times in both the baseline and intervention periods
- The analyses were performed as independent, but certainly they are not. Below can be seen the analyses for repeated measures. The methodology used was GLM repeated measures. The data are based on the common journeys and the average speed has bee compared for the same journeys in two different periods. Period 1 is the baseline period whereas period 2 is when the functions were available for use.

3.3.1.6 Statistical Testing

The means from the paired journeys conditions (control and treatment) of the UK-DFOT2 were analysed using a Paired Samples T-test.

ES-DFOT1 and the LFOTs were analysed using univariate general model.

H_0: The distributions can be considered the same against the alternative hypothesis

H_1: The distributions are different.

For the LFOT data it was used homogeneity of variance tests also.

H_0: There are no differences between two or more variances

H_1: There are differences between two or more variances

3.3.2. Results

3.3.2.1 UK-DFOT2

Data from UK-DFOT2 showed a significant change in the speed distribution between both conditions (baseline and treatment).

The average speed analysis showed significant difference in average speed between the control condition and intervention condition for the journey as a whole for those 27 drivers. Since this is contradictory to RQ1, it will be explained hereafter. The analysis of this research question is based on logged data of the Foot-LITE system. The logging functionality was not really reliable. That is also the reason why only 27 of 40 subjects have a full data set. Another data logger was available at the UK testsite which was more reliable. This data logger was used to answer RQ1 and therewith data of 38 of 40 participants was available. This analysis showed that there was no significant change in average speed.

The distributions can be considered different in the control and intervention conditions, but this is also based on the poor logging tool with only 27 of 40 test subjects.

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Vehicle_speed_mean_Con	50.99	27	4.50	0.87
	Vehicle_speed_mean_FL	47.88	27	2.84	0.55
Pair 2	Vehicle_speed_GPS_mean_Con	50.92	27	4.32	0.83
	Vehicle_speed_GPS_mean_FL	48.27	27	2.86	0.55

Table 6: Average speed analysis

	Paired Differences		t	df	Sig. (2-tailed)
	Mean	Std. Deviation			

Pair 1	Vehicle_speed_mean_Con – Vehicle_speed_mean_FL	3.11	5.02	3.22	26	.003
Pair 2	Vehicle_speed_GPS_mean_Con – Vehicle_speed_GPS_mean_FL	2.65	4.88	2.82	26	.009

Table 7: Speed distribution

3.3.2.2 ES-DFOT1

The result of the ES-DFOT1 data showed no significant change in the speed distribution between both conditions (baseline and treatment).

The speed of the vehicle was logged with two devices. The Blom device which was used in ES-LFOT1 and an additional CAN-bus system was installed. The results from the BLOM and the internal device are shown in the figures below (refer Figure 15 to Figure 18)

Descriptive Statistics

Dependent Variable:Speed

Condition	Mean	Std. Deviation	N
Device	29.9560	21.20491	2870
Baseline	30.7552	21.19663	2081
Total	30.2919	21.20296	4951

Figure 15: Descriptive statistics (BLOM device)

Tests of Between-Subjects Effects

Dependent Variable:Speed

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	770,608[a]	1	770,608	1,714	,190
Intercept	4446303,419	1	4446303,419	9891,650	,000
Condition	770,608	1	770,608	1,714	,190
Error	2224578,781	4949	449,501		
Total	6768391,726	4951			
Corrected Total	2225349,389	4950			

a. R Squared = ,000 (Adjusted R Squared = ,000)

Figure 16: Tests of Between-Subjects effects (BLOM device)

Descriptive Statistics

Dependent Variable:Speed_mean

Condition	Mean	Std. Deviation	N
Device	30,1641	21,49695	2952
Baseline	30,6159	21,00419	2839
Total	30,3856	21,25617	5791

Figure 17: Descriptive statistics (internal vehicle device)

Tests of Between-Subjects Effects

Dependent Variable:Speed_mean

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	295,429[a]	1	295,429	,654	,419
Intercept	5346261,693	1	5346261,693	11831,889	,000
Condition	295,429	1	295,429	,654	,419
Error	2615770,721	5789	451,852		
Total	7962812,794	5791			
Corrected Total	2616066,151	5790			

a. R Squared = ,000 (Adjusted R Squared = ,000)

Figure 18: Tests of Between-Subjects effects (internal vehicle device)

The conclusion from the figures is that there is no difference in average speed among the two conditions.

3.3.2.3 SWE-LFOT2

First of all, Levene´s test showed differences in the variance of the baseline and treatment periods. From the analysis of variance and the descriptive statistics can be seen that speed distribution is different among the periods and speed average has been increased when the functions were available for their use (Table 8, Table 9, Table 10).

Levene's Test of Equality of Error Variances[a]

Dependent Variable:avg_velocity

F	df1	df2	Sig.
48,751	1	6413	,000

Table 8: Levene’s Test of Equality of ErrorVariances

Tests of Between-Subjects Effects

Dependent Variable:avg_velocity

Source	Type III Sum of Squares	df	Mean Square	F	Sig.

Corrected Model	32243,389[a]	1	32243,389	105,635	,000
Intercept	7883296,768	1	7883296,768	25827,175	,000
Period	32243,389	1	32243,389	105,635	,000
Error	1957456,928	6413	305,233		
Total	10128194,786	6415			
Corrected Total	1989700,317	6414			

Table 9: Tests of Between-Subjects Effects

Period				
Dependent Variable:avg_velocity				
			95% Confidence Interval	
Period	Mean	Std. Error	Lower Bound	Upper Bound
Baseline	33,075	,330	32,428	33,722
Treatment	37,595	,291	37,025	38,165

Table 10: Period

3.3.2.4 FIN-LFOT

There are no significant differences either in the average speed or the speed variance in the FIN-LFOT (Table 11, Table 12, Table 13).

Levene's Test of Equality of Error Variances[a]			
Dependent Variable:avg_velocity_when_driving			
F	df1	df2	Sig.
,907	1	1726	,341

Table 11: Levene's Test of Equality of Error Variances

Tests of Between-Subjects Effects					
Dependent Variable:avg_velocity_when_driving					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	705,559[a]	1	705,559	1,895	,169
Intercept	2742283,106	1	2742283,106	7363,794	,000
Period2	705,559	1	705,559	1,895	,169
Error	642763,842	1726	372,401		
Total	4456821,610	1728			
Corrected Total	643469,401	1727			

Table 12: Tests of Between-Subjects Effects

Period
Dependent Variable:avg_velocity_when_driving

Period2	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Baseline	45,842	,946	43,986	47,698
Treatment	47,336	,533	46,291	48,381

Table 13: Period

3.3.2.5 IT-LFOT

In the IT-LFOT happened something similar to the Finnish one. There are no significant differences either in the average speed or the speed variance in the IT-LFOT (Table 14, Table 15, Table 16).

Levene's Test of Equality of Error Variances[a]			
Dependent Variable:avg_velocity_when_driving			
F	df1	df2	Sig.
,186	1	71	,667

Table 14: Levene's Test of Equality of Error Variances

Tests of Between-Subjects Effects					
Dependent Variable:avg_velocity_when_driving					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	536,482[a]	1	536,482	,831	,365
Intercept	218674,616	1	218674,616	338,720	,000
Period	536,482	1	536,482	,831	,365
Error	45837,026	71	645,592		
Total	264792,466	73			
Corrected Total	46373,508	72			

Table 15: Tests of Between-Subjects Effects

Period				
Dependent Variable:avg_velocity_when_driving				
Period	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Baseline	52,026	4,177	43,697	60,354
Treatment	57,448	4,235	49,004	65,892

Table 16: Period

3.3.2.6 ES-LFOT1

Data from ES-LFOT1 show that even the speed average changed, its variance remains the same among the two periods (Table 17, Table 18, Table 19).

Levene's Test of Equality of Error Variances[a]			
Dependent Variable:avg_velocity			
F	df1	df2	Sig.
,383	1	1164	,536

Table 17: Levene's Test of Equality of Error Variances

Tests of Between-Subjects Effects					
Dependent Variable:avg_velocity					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3478,257[a]	1	3478,257	9,138	,003
Intercept	3332769,398	1	3332769,398	8755,880	,000
Period	3478,257	1	3478,257	9,138	,003
Error	443055,835	1164	380,632		
Total	4110841,570	1166			
Corrected Total	446534,092	1165			

Table 18: Tests of Between-Subjects Effects

Period				
Dependent Variable:avg_velocity				
			95% Confidence Interval	
Period	Mean	Std. Error	Lower Bound	Upper Bound
Baseline	53,774	,947	51,915	55,633
Device	57,365	,716	55,960	58,770

Table 19: Period

3.3.2.7 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 its use but not the journeys, or the specific time that they were activated.

3.3.2.8 Discussion and Conclusions from the Data Analysis

Data from two out of the three test site using the green driving function showed differences in the speed distribution, but opposite to what it was expected. Average speed and speed variance are smaller while using this function. The rest of the test sites and functions did not show any differences in the speed distribution.

FOT	Functions	Main results
UK-DFOT2	Green Driving	Change in the speed distribution. Variance and speed are smaller when using the GD function (based on poor data quality)
ES-DFOT1	Speed Information/Speed Alert	No significant change in the speed distribution
SWE-LFOT2	Navigation, Traffic information, Green Driving	Change in the speed distribution. Variance and speed are greater when the functions were available for its use.
FIN-LFOT	Traffic information, Speed Information/Speed alert, Green Driving	No significant change in the speed distribution
II-LFOT	Speed Information/Speed Alert, Navigation	No significant change in the speed distribution
ES-LFOT1	Speed Information/Speed Alert, Navigation	No significant change in the speed distribution

Table 20: Overview of used functions and test results

It should be considered to analyse data from perspective. The DFOT data are very accurate but there is no time perspective, which is basic to analyse the changes in speed distribution, because it is difficult that participants change their habits from one test to the next one. Also, users perceived that an eco-driving style lead to increased journey time as a result of the driver simply driving slower (therefore lower average speeds).

Concerning the LFOT data it has to be mentioned that what it has been analysed are the periods when the baseline was activated or the functions were available to be considered jointly with the average speed distribution.

One thought is that if the spread of the speed distribution is reduced, fuel can be saved because a smoother velocity profile can be achieved through less acceleration. But the reality is, for this to happen, the speed vehicles measured should be taken in similar circumstances. Some speed distributions are of vehicles in a traffic stream. Others may include vehicles at a variety of places and times under diverse flow and environmental conditions. The road type and characteristics make a great impact on the speed distribution. Sometimes speeds are measured over a long length of time with a low traffic flow. Indeed, in many cases the vehicles whose speeds are being measured may have no interaction at all because they are so widely spaced in time.

The DFOT tests tried to minimise the uncertainty coming from the external conditions (weather, road type, time,…) but still some circumstances as the traffic flow that obviously were not controlled. To investigate deeply the speed distribution the experiment might be carried on in a closed test track.

3.4. Number of journeys

In this chapter the fourth Research question of the environmental impact assessment, Env-RQ4: “Is number of journeys affected?” is addressed. With this research question the hypothesis H4.1: “There is an increase / decrease in number of journeys” is about to be answered with the help of the data logged during the test runs.

3.4.1. Data used

In this chapter the data used for the evaluation is described in detail. Therefore the different data types and specifics of the used data are given in detail.

3.4.1.1 Data types

In Table 21 the different functions tested in the given FOTs are listed. Beneath the functions the corresponding data type and the number of subjects participating in the FOTs are given.

FOT	Function / s	Data Type	Number of participants			
			Baseline	Treatment		
			TD1	TD2	TD3	TD4
FIN-LFOT	GD, SI/SA, TI	Travel diary	93	69	57	38

GR-LFOT	NA, SI, SA, TI	Travel diary	132	105	111	107
IT-LFOT	NA, SI/SA	Travel diary	118	86	30	–
ES-LFOT1	NA, SI/SA	Travel diary	118	99	92	95
SWE-LFOT2	GD, NA, TI	Travel diary	86	52	60	–
UK-LFOT	NA, SI/SA	Travel diary	60	56	52	44

Table 21: Data used for the analysis of EnvRQ4

3.4.1.2 Data selection and filtering

All test sites were included in the analysis, except for the Greek test site, where there was only one travel diary by function for all participants. Furthermore, all participants who had filled all the travel diaries for more than one day were included.

3.4.2. Results

The results are divided into several sections. Firstly, the analysis of seasonal trends is shown before the results of the different functions or bundles are presented.

3.4.2.1 Seasonal trends:

The seasonal trends in number of car journeys were studied with those Finnish participants who had only traffic information service throughout the study (Table 22).

FOT	Functions (baseline/treatment)	Period1	Period2	Period3	N
FIN-LFOT	TI / TI	3.1	3.2	2.8	5

Table 22: Average number of journeys per period

In Finland, the seasonal differences in weather are the strongest within TeleFOT countries. Nevertheless, the variation in number of car journeys was very mild (measured in winter time, late spring and autumn) and statistically insignificant.

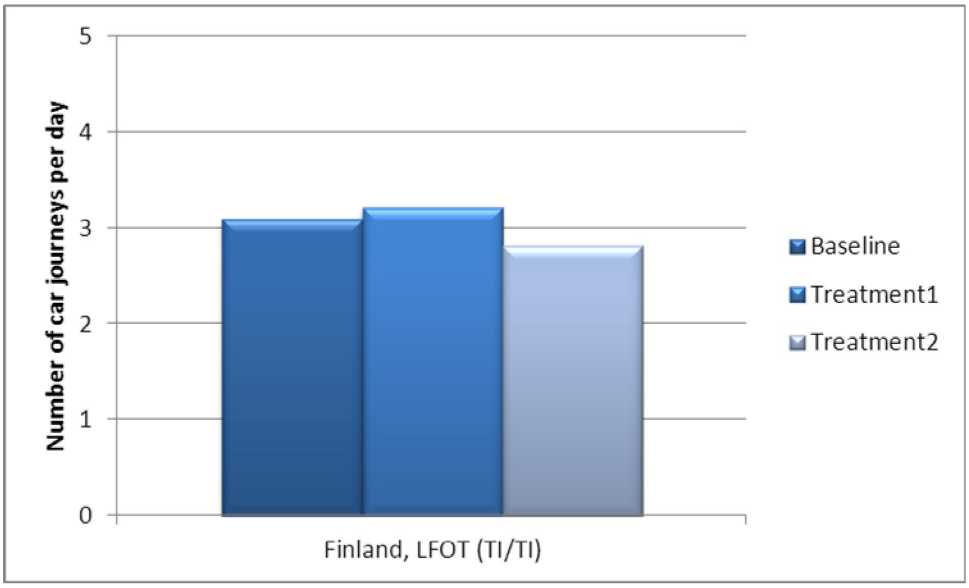

Figure 19: Number of car Journeys per day

FOT	Assumption for sphericity[1]	df	F	P
FIN-LFOT	OK	2	0.975	0.418

Table 23: Statistical significance of differences between travel diaries, ANOVA with repeated measures ([1]Tested with Mauchly's Test of Sphericity)

3.4.2.2 Green driving

There were no statistically significant changes in number of journeys due to getting the green driving application.

FOT	Functions (baseline/treatment)	Period1	Period2	Period3	Period4	N
FIN-LFOT	TI / TI+GD	3.9	4.6	5.0	–	3
	TI+SI / TI+GD	3.4	2.8	2.7	3.1	12
	TI+SI / TI+SI+GD	3.7	3.2	4.0	3.0	11

Table 24: Average number of journeys per period

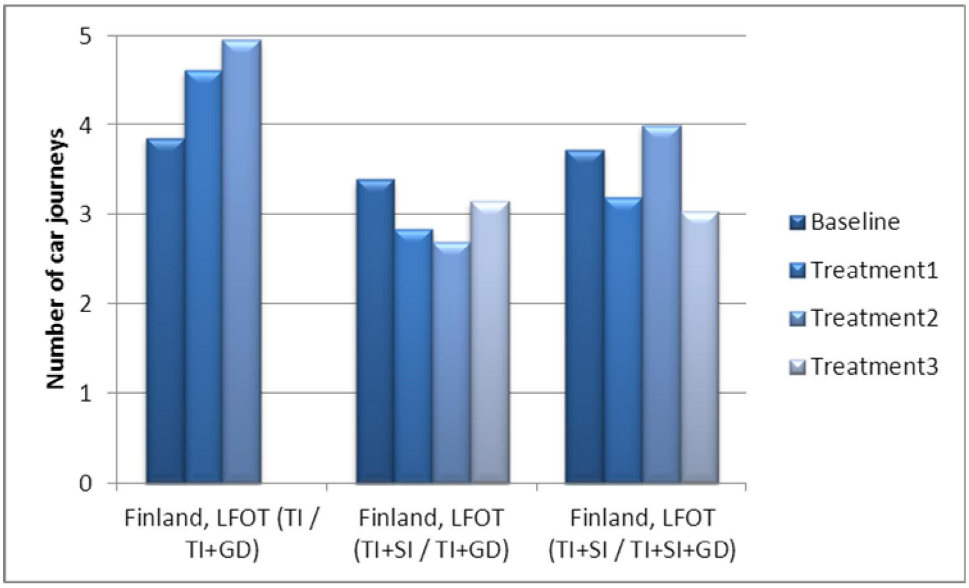

Figure 20: Number of car journeys

FOT	Assumption for sphericity[1]	df	F	P
FIN-LFOT (1)	OK	2	2.414	0.205
FIN-LFOT (2)	OK	3	1.248	0.308
FIN-LFOT (3)	OK	3	1.782	0.172

Table 25: Statistical significance of differences between travel diaries, ANOVA with repeated measures [1]Tested with Mauchly's Test of Sphericity)

3.4.2.3 Speed limit information

There were no statistically significant changes in number of journeys between the period when speed limit information/alert was in use and when not in use.

FOT	Functions (baseline/treatment)	Period1	Period2	Period3	Period4	N
FIN- LFOT	TI+SI / TI	3.1	3.5	3.2	3.6	5

Table 26: Average number of journeys per period

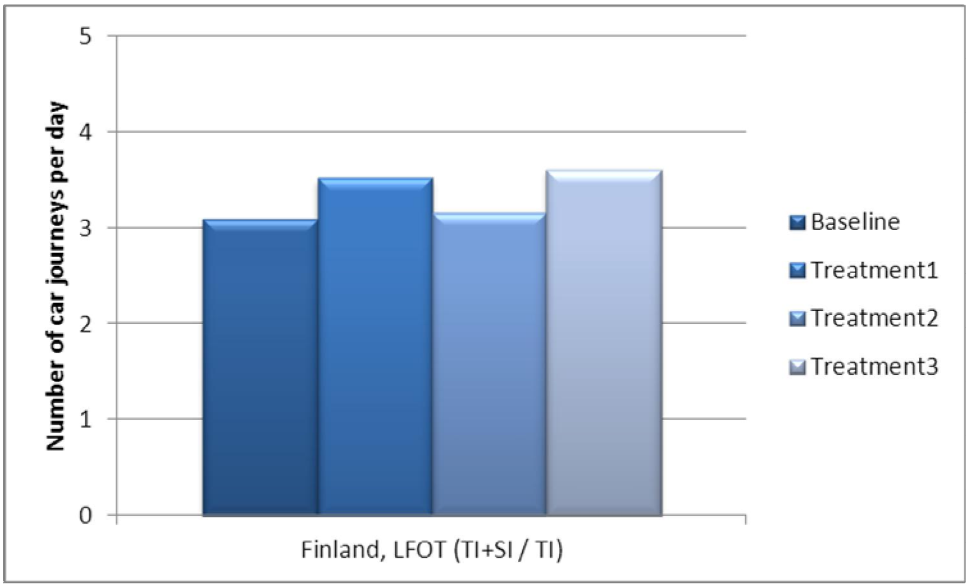

Figure 21: Number of journeys per day

FOT	Assumption for sphericity[1]	Df	F	p
FIN-LFOT	OK	3	0.751	0.542

Table 27: Statistical significance of differences between travel diaries, ANOVA with repeated measures ([1]Tested with Mauchly's Test of Sphericity)

3.4.2.4 Bundle: green driving and speed limit information/alert

There were no statistically significant changes in number of journeys due to getting the bundle of green driving application and speed limit information/alert.

FOT	Functions (baseline/treatment)	Period1	Period2	Period3	N
FIN-LFOT	TI / TI+GD+SI	3.4	3.1	3.3	4

Table 28: Average number of journeys per period

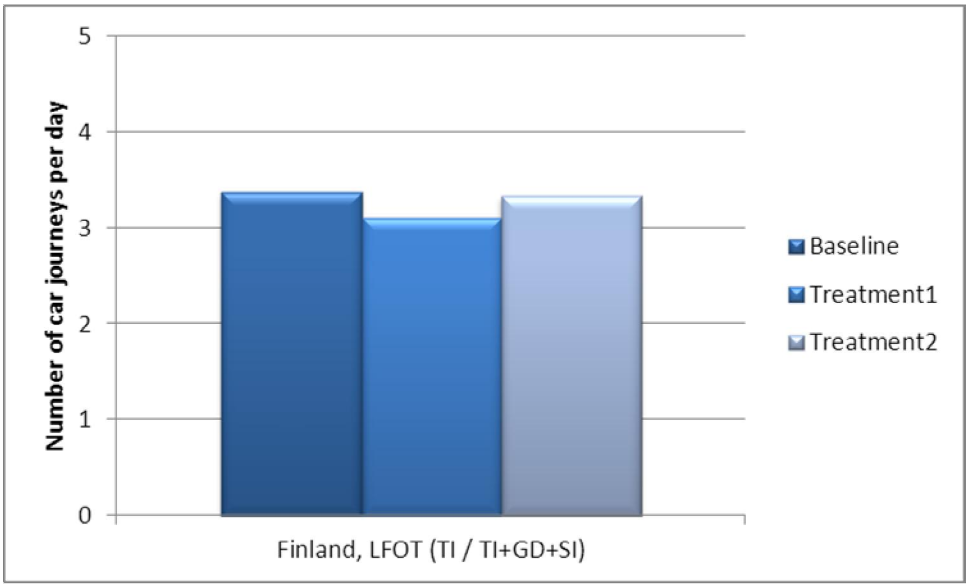

Figure 22: Number of car journeys per day

FOT	Assumption for sphericity[1]	df	F	p
FIN-LFOT	OK	2	0.103	0.904

Table 29: Statistical significance of differences between travel diaries, ANOVA with repeated measures ([1]Tested with Mauchly's Test of Sphericity)

3.4.2.5 Bundle: navigation and speed limit information/alert

There were no statistically significant changes in number of journeys due to getting the bundle of navigation and speed limit information/alert.

FOT	Functions (baseline/treatment)	Period1	Period2	Period3	Period4	N
IT-LFOT	–/NA+SI	3.9	3.9	4.2	–	26
ES-LFOT1	–/NA+SI	3.2	3.2	3.1	3.0	86
UK-LFOT	–/NA+SI	3.2	2.8	3.0	2.9	36

Table 30: Average number of journeys per period

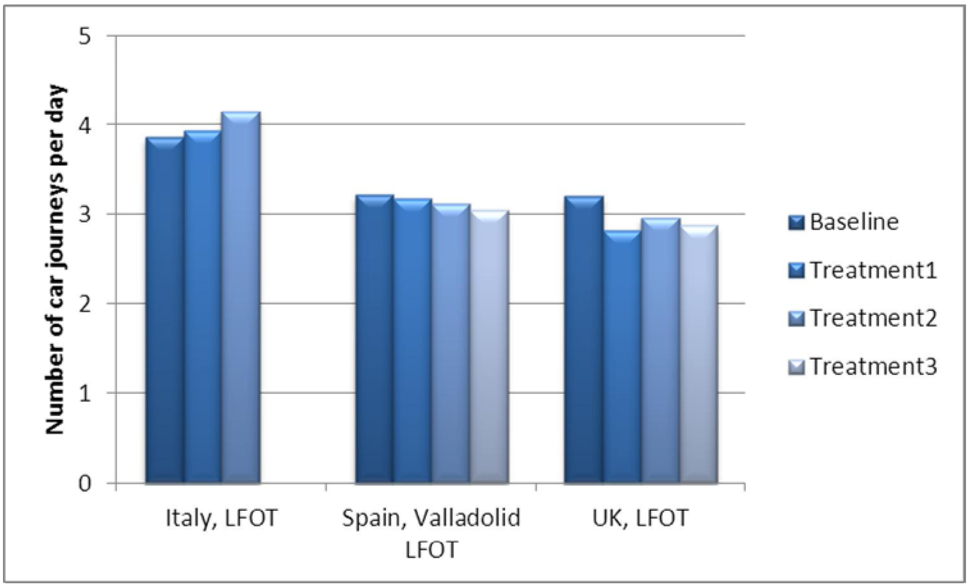

Figure 23: Number of car journeys per day

FOT	Assumption for sphericity	df	F	p
IT-LFOT	Violated[1]	1.582	0.713	0.465
ES-LFOT1	Violated[1]	2.694	0.526	0.645
UK-LFOT	OK	3	1.380	0.253

Table 31: Statistical significance of differences between travel diaries, ANOVA with repeated measures ([1]A significant value for Mauchly's Test of Sphericity)

The sphericity for Italy (0.025) and Spain (0.019) indicates that the assumption of sphericity has been violated. Therefore an ANOVA with repeated measures with a Greenhouse-Geisser correction was used.

3.4.2.6 Bundle: navigation, green driving and traffic information

There were no statistically significant changes in number of journeys due to getting the bundle of navigation, green driving application and traffic information.

FOT	Functions (baseline/treatment)	Period1	Period2	Period3	N
SWE-LFOT2	– / NA+GD+SI	2.9	2.9	3.0	42

Table 32: Average number of journeys per period

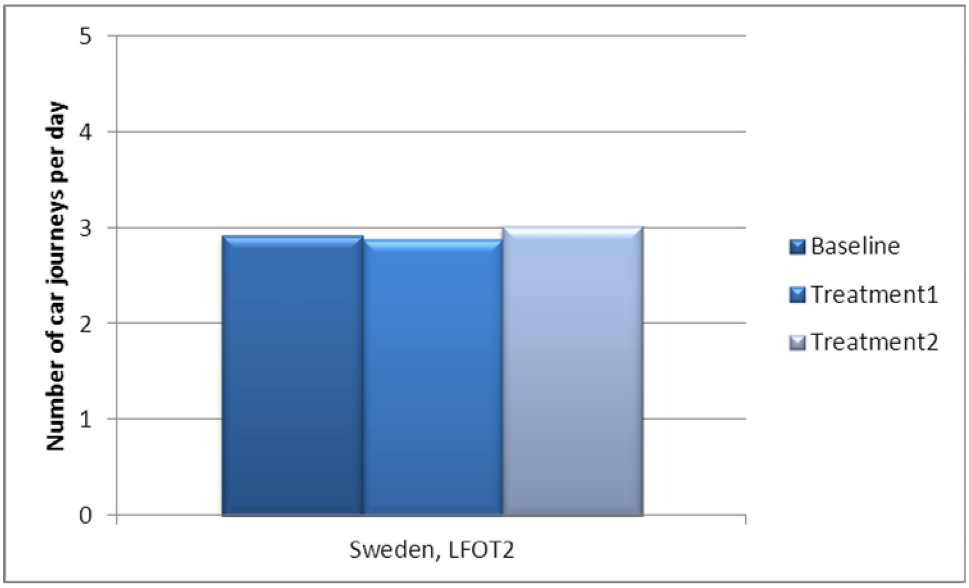

Figure 24: Number of car journeys per day

FOT	Assumption for sphericity[1]	df	F	p
SWE-LFOT2	OK	2	0.260	0.772

Table 33: Statistical significance of differences between travel diaries, ANOVA with repeated measures ([1]Tested with Mauchly's Test of Sphericity)

Correlations to background variables were not determined because there were no statistically significant differences between travel diaries.

Travel diary data was in concordance with questionnaire data only for the Finnish LFOT with green driving support and speed limit information. For other functions and LFOTs the results were not consistent, and the perceived changes were not in the same direction (decrease/increase).

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

Travel diary data was used to assess the research question “Is the number of journeys affected?”. However, the results indicated that none of the functions or bundles of function had statistically significant impact on number of car journeys in any of the FOTs.

3.5. Distance travelled

In this chapter the fifth research question of the environmental impact assessment, Env-RQ5: "Is the distance travelled affected?" is addressed. With this research question the hypothesis H5.1: "There is an increase/ decrease in travelled distance" is about to be answered with the help of the data logged during the test runs.

3.5.1. Data used

In this chapter the data used for the evaluation is described in detail. Therefore the different data types and specifics of the used data are given in detail.

3.5.1.1 Data types

In Table 34 the different functions tested in the given FOTs are listed. Beneath the functions the corresponding data type and the number of subjects participating as well as the total driving kilometres and the total driving hours in the FOTs are given.

FOT	Function / s	Data Type	Number of participants	Total driving km	Total driving hours
FIN-LFOT	GD, SI/SA, TI	Logged	125	334 013	7 489
IT-LFOT	NA, SI/SA	Logged	150	3 325 630	72 312
ES-LFOT1	NA, SI/SA	Logged	120	871 508	19 516
ES-LFOT2	GD, TI	Logged	132	1 446 316	58 025
SWE-LFOT2	GD, NA, TI	Logged	87	622 244	12 865

SWE-LFOT4	TI	Logged	260	465 075	7 944
UK-LFOT	NA, SI/SA	Logged	60	192 740	3 785
GR-LFOT	NA, SI, SA, TI	Logged	148	805 456	18 842

Table 34: Data used for the analysis of EnvRQ5

3.5.1.2 Data selection and filtering

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. Participants contributed varying number of these pairs. Outliers that were substantially outside the data distribution were removed. In most cases a limit of four times standard deviation was used.

Mean 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.

3.5.2. Results

Statistical significance of distance driven between different OD pairs was calculated by function bundle. Those Finnish participants who had only traffic information service in use throughout the FOT did not have statistically significant impacts on distance driven between comparable origins and destinations.

The only statistically significant differences were that the distance was for function pair traffic information and green driving support 9.6% longer than for traffic information and speed limit information/alert in Finnish LFOT and 2.5% shorter with the bundle navigation and speed limit information/alert than without any functions in ES-LFOT1.

FOT	Functions		N	Distance (km)				t	p
	Baseline	Treatment		Mean, baseline	Mean, treatment	St. dev., baseline	St. dev., treatment		
FIN-LFOT	TI	TI	12	13.7	13.8	7.3	8.0	-0.202	0.844
FIN-LFOT	TI	TI, GD, SI/SA	8	30.8	29.7	31.2	31.4	0.536	0.608
FIN-LFOT	TI, SI/SA	TI	50	20.3	19.7	14.6	13.0	0.363	0.718
FIN-LFOT	TI, SI/SA	TI, GD	193	22.8	25.0	31.1	31.9	-1.898	0.059*
FIN-LFOT	TI, SI/SA	TI, SI/SA, GD	75	16.8	18.3	17.5	17.8	-1.194	0.236
FIN-LFOT	TI, GD	TI, GD, SI/SA	85	16.6	17.9	18.5	18.7	-1.487	0.141
ES-LFOT1	–	NAV, SI/SA	1174	15.9	15.5	15.0	14.6	2.696	0.007**
ES-LFOT2	–	DG	7819	3.25	3.26	3.85	3.95	-0.810	0.418
ES-LFOT2	–	TI	6447	2.75	2.74	2.67	2.46	0.347	0.729
UK-LFOT	–	NAV, SI/SA	291	13.2	13.5	19.4	20.3	-0.669	0.504
IT-LFOT	–	NAV, SI/SA	3897	7.56	7.62	15.5	15.8	-0.825	0.409
SWE-LFOT4	–	TI	268	23.7	23.7	25.1	25.3	-0.003	0.998
SWE-LFOT2	–	GD, NAV, TI	1165	11.7	11.9	16.2	16.4	-1.410	0.159
GR-LFOT1	–	NAV	414	13.5	13.1	18.3	17.8	1.362	0.174
GR-LFOT2	NAV	NAV, SI	455	13.7	15.5	18.7	37.2	-1.165	0.245
GR-LFOT3	NAV	NAV, TI	430	18.5	17.6	29.9	29.2	1.551	0.122
GR-LFOT4	NAV	NAV, SA	543	17.8	17.1	28.5	23.4	0.894	0.372

Table 35: Mean distance between comparable OD pairs in baseline and treatment phase as well as the statistical values describing the difference

Plots were made for those data that indicated statistically significant impact on duration. Most observations lie very close to the line y = x.

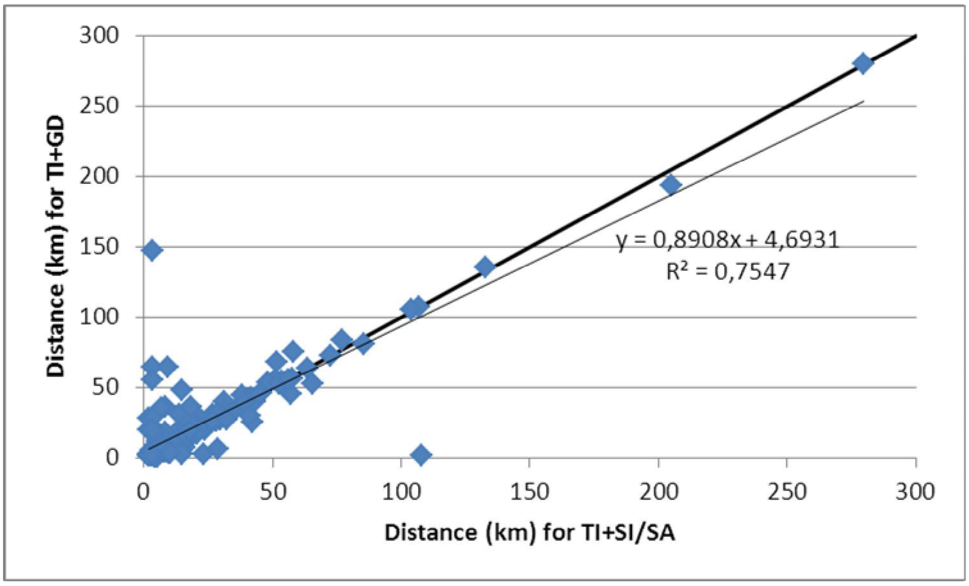

Figure 25: Difference in distance driven between comparable origins and destinations when comparing traffic information and speed limit information/alert to traffic information and green driving, Finland LFOT

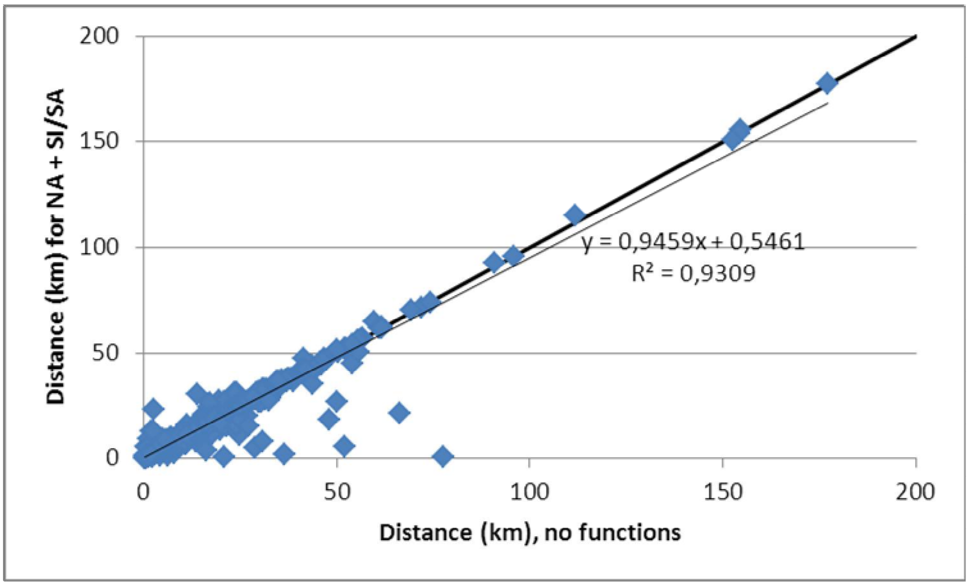

Figure 26: Difference in distance driven between comparable origins and destinations when comparing the bundle "navigation and speed limit information/alert" with no functions, Spain Valladolid LFOT

FOT	Functions		N	Distance longer in Baseline conditions	Distance at least 10% longer in baseline conditions	Distance at least 10% longer in treatment conditions
	Baseline	Treatment				
FIN-LFOT	TI	TI	12	41.7	8.3	16.7
FIN-LFOT	TI	TI, GD, SI/SA	8	37.5	25.0	12.5
FIN-LFOT	TI, SI/SA	TI	50	50.0	26.0	34.0
FIN-LFOT	TI, SI/SA	TI, GD	193	48.2	21.2	25.9
FIN-LFOT	TI, SI/SA	TI, SI/SA, GD	75	50.7	21.3	28.0
FIN-LFOT	TI, GD	TI, GD, SI/SA		37.6	16.5	27.1
ES-LFOT1	–	NAV, SI/SA	1029	51.6	12.2	10.2
ES-LFOT2	-	GD	7818	44.5	18.5	19.0
ES-LFOT2	-	TI	6447	42.7	18.4	19.0
UK-LFOT	–	NAV, SI/SA	291	48.8	24.7	21.0
IT-LFOT	–	NAV, SI/SA	3897	43.5	10.5	17.1
SWE-LFOT4	–	TI	268	54.1	13.1	12.3
SWE-LFOT2	–	GD, NAV, TI	1165	47.1	19.6	19.0
GR-LFOT1	-	NAV	414	60.6	27.8	16.7
GR-LFOT2	NAV	NAV, SI	455	56.1	20.2	18.0
GR-LFOT3	NAV	NAV, TI	430	66.1	30.1	16.0
GR-LFOT4	NAV	NAV, SA	543	56.4	23.0	16.7

Table 36: Proportion of OD pairs with difference in distance. If there is no impact the distance should be longer in 50% of OD pairs in treatment and shorter in 50% of OD pairs in baseline and there should not be over 10% differences

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

With green driving support, the questionnaire data did not support the logger data on changes in distance. With speed limit information/alert, the logger data supported the questionnaire data in the Greek (speed alert) and the Valladolid LFOTs, but not in the Finnish, Greek, UK or Italian LFOTs. With traffic information, the logger data was in complete concordance with questionnaire data. With navigation, the results were compatible only for Greek LFOT 1 and Valladolid LFOT.

The only statistically significant differences between baseline and treatment means in logger data were for Valladolid LFOT with bundle of navigation and speed limit information/alert and Finnish LFOT with bundle of traffic information and green driving support. The Finnish results were not clear, but in the Valladolid LFOT logger data was in concordance with the questionnaire data. In both of the functions, there was a decrease of distance during trial. However, in the logger data the bundle might have had an effect and the questionnaire was functioning specific.

The connection between logger and questionnaire data by participant groups was calculated for the Valladolid LFOT (navigation and speed limit information/alert), where the logger data showed significant differences between treatment and baseline means. The logger data was in concordance with the questionnaire data also on participant group level for navigation. The participants who had replied 'decrease' in the questionnaire had also a slightly smaller treatment mean than baseline mean and more participants had a negative change in logger data. For speed limit information/alert there were more participants whose journey distance had increased even though in the questionnaire they reported decrease.

LFOT/function (questionnaire)	Function bundle (log)	Change (questionnaire)	Mean (treatment-baseline), log	Standard deviation	Positive values (%)	Negative values (%)	N
ES-LFOT1, Speed information/alert	SI/SA, NAV	decrease	-0.80	2.43	60	40	10
ES-LFOT1, Navigation	SI/SA, NAV	decrease	-0.42	1.33	44	56	35

Table 37: Change direction for distance in questionnaire and logger data

3.5.2.1 Results by background variables

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

There was strong dependence between the previous function use variables, which might have contributed to the analyses. Age was classified into four groups (1934-1949, 1950-1965, 1966-1981 and 1982-1997). Because of uneven distributions, age could be studied for Finnish LFOT, Swedish LFOT 2, Italian LFOT and UK LFOT, and gender for Swedish LFOT 2 and UK LFOT. Familiarity of function use was determined with four alternatives: no experience on function, some previous information on function but no use experience, some use experience and considerable use experience. Most drivers described themselves as balanced drivers (42-84%), so differences between groups were not studied in regard to driving style.

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

3.5.2.2 Age

In the following the influence of age on the journey distance has been regarded.

Change	1	2	3	4
other	3%	22%	39%	3%
increase	0%	11%	19%	3%

Table 38: Change in journey distance compared to age group, Finland LFOT, bundle traffic information & green driving support

LFOT	function	N	Chi-square	p
Finland	GDS	36	0.750	0.861

Table 39: Chi-square test results between change in journey distance and age group

No statistically significant differences between questionnaires.

3.5.2.3 Familiarity with functions

In the following the influence of familiarity of the driver with the tested functions on the journey distance has been regarded.

Change	not at all	never used	some experience
other	3%	53%	11%
increase	0%	25%	8%

Table 40: Change in journey distance compared to previous function use experience, Finland, green driving support (TI+SI/SA->TI+GD)

Change	never used	some experience	considerable use
other	6%	44%	17%
increase	8%	19%	6%

Table 41: Change in journey distance compared to previous function use experience, Finland, speed limit information

Change	never used	some information	considerable use
other	19%	33%	14%
increase	14%	11%	8%

Table 42: Change in journey distance compared to previous function use experience, Finland, speed alert

Change	not at all	never used	some experience	considerable use
decrease	1%	4%	5%	0%
other	9%	13%	52%	17%

Table 43: Change in journey distance compared to previous function use experience, Spain, navigation

Change	not at all	never used	some experience	considerable use
decrease	2%	2%	5%	1%
other	9%	18%	45%	19%

Table 44: Change in journey distance compared to previous function use experience, Spain, speed limit information

Change	not at all	never used	some experience	considerable use
decrease	2%	2%	5%	1%
other	8%	19%	52%	12%

Table 45: Change in journey distance compared to previous function use experience, Spain, speed alert

LFOT	Function	N	Chi-square	p
Finland	GDS	36	0.804	0.669
	SI	36	1.937	0.380
	SA	36	0.938	0.626
ES-LFOT1	NAV	102	5.562	0.135
	SI	102	1.396	0.706
	SA	102	1.335	0.721

Table 46: Chi-square test results between change in journey distance and previous function use experience

No statistically significant differences between questionnaires.

3.5.2.4 Rush hour journeys

Difference between baseline and treatment means was larger than those during rush hour in all OD pairs for most LFOTs. Rush hour was determined to be 7-9 a.m. and 3-6 p.m. Only the UK LFOT, Finnish LFOT with green driving support and speed limit information/alert, Madrid LFOT with TI and Greek LFOT 4 (SA) had a smaller difference between baseline and treatment means for all OD pairs. For Finnish (SI/SA), UK and Greek LFOT 2 (SI) the difference in baseline and treatment means was in a different direction for rush hour OD pairs when compared to all OD pairs. However, the differences were quite small in all cases.

Spain Valladolid LFOT and Finnish LFOT with green driving support and speed limit information/alert had a statistically significant difference between baseline and treatment means for all OD pairs. For rush hour traffic, however, there was no statistically significant result in Spanish Valladolid LFOT.

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

FOT	Functions		N	Distance (km)				t	p
	Baseline	Treatment		Mean, baseline	Mean, treatment	St. dev., baseline	St. dev., treatment		
FIN-LFOT	TI	TI	12	13.7	13.8	7.3	8.0	-0.202	0.844
FIN-LFOT	TI	TI, GDS, SI/SA	8	30.8	29.7	31.2	31.4	0.536	0.608
FIN-LFOT	TI, SI/SA	TI	49 (25)	19.4 (21.2)	20.1 (21.2)	13.4 (16.0)	12.9 (15.1)	-0.729 (-0.067)	0.470 (0.947)
FIN-LFOT	TI, SI/SA	TI, GDS	193 (90)	22.8 (16.9)	25.0 (19.2)	31.1 (13.0)	31.9 (14.9)	-1.898 (-2.275)	0.059* (0.025**)
FIN-LFOT	TI, SI/SA	TI, SI/SA, GDS	75 (26)	16.8 (14.1)	18.3 (15.9)	17.5 (13.4)	17.8 (11.9)	-1.194 (-0.994)	0.236 (0.330)
FIN-LFOT	TI, GDS	TI, GDS, SI/SA	85 (16)	16.6 (13.0)	17.9 (12.0)	18.5 (6.3)	18.7 (6.6)	-1.487 (1.413)	0.141 (0.178)
ES-LFOT1	–	NAV, SI/SA	1174 (120)	15.9 (17.6)	15.5 (17.6)	15.0 (13.0)	14.6 (13.2)	2.696 (-0.037)	0.007** (0.970)
ES-LFOT2	–	DG	7819 (2098)	3.25 (2.90)	3.26 (2.91)	3.85 (3.26)	3.95 (3.32)	-0.810 (-1.196)	0.418 (0.232)
ES-LFOT2	–	TI	6447 (1748)	2.75 (2.45)	2.74 (2.40)	2.67 (2.34)	2.46 (2.16)	0.347 (1.434)	0.729 (0.152)
UK-LFOT	–	NAV, SI/SA	291	13.2 (19.0)	13.5 (18.8)	19.4 (23.3)	20.3 (23.2)	-0.669 (0.752)	0.504 (0.453)
IT-LFOT	–	NAV, SI/SA	3897 ()	7.56 (7.01)	7.62 (7.01)	15.5 (14.4)	15.8 (14.3)	-0.825 (-0.014)	0.409 (0.898)
SWE-LFOT4	–	TI	265	22.4 (21.6)	22.8 (22.3)	22.9 (21.3)	23.2 (22.0)	-1.567 (-1.06)	0.118 (0.292)

SWE-LFOT2	–	GD, NAV, TI	1165	11.7 (11.1)	11.9 (11.5)	16.2 (15.2)	16.4 (15.7)	-1.410 (-1.214)	0.159 (0.225)
GR-LFOT1	–	NAV	414	13.5 (12.1)	13.1 (11.8)	18.3 (10.3)	17.8 (10.2)	1.362 (1.289)	0.174 (0.200)
GR-LFOT2	NAV	NAV, SI	455	13.7 (15.6)	15.5 (15.1)	18.7 (16.5)	37.2 (17.5)	-1.165 (1.158)	0.245 (0.249)
GR-LFOT3	NAV	NAV, TI	430	18.5 (20.3)	17.6 (19.9)	29.9 (25.2)	29.2 (28.3)	1.551 (0.398)	0.122 (0.692)
GR-LFOT4	NAV	NAV, SA	543	17.8 (17.0)	17.1 (16.5)	28.5 (15.2)	23.4 (13.9)	0.894 (1.582)	0.372 (0.115)

Table 47: Mean distance between comparable OD pairs in baseline and treatment phase as well as the statistical values describing the difference. (Mean distance between comparable rush hour OD pairs in baseline and treatment phase as well as the statistical values describing the difference.)

3.5.2.5 Daytime journeys

Daytime was determined to be outside the rush hours from 9 a.m. to 3 p.m. Difference between baseline and treatment means was larger in all OD pairs than during only daytime journeys for most LFOTs. Only the UK LFOT, Finnish LFOT with green driving support and speed limit information and Swedish LFOT 4 had a smaller difference between baseline and treatment means for all OD pairs. For UK LFOT, Finnish LFOT with green driving support, Madrid LFOT with TI and Greek LFOT 3 (TI) the difference in baseline and treatment means was in a different direction for daytime journey OD pairs when compared to all OD pairs. However, the differences were quite small in all cases.

Spain Valladolid LFOT and Finnish LFOT with green driving support and speed limit information/alert had a statistically significant difference between baseline and treatment means for all OD pairs. For daytime journeys, however, there was no statistically significant result in Spanish Valladolid LFOT.

Swedish LFOT 4 did not have a statistically significant difference between baseline and treatment means for all OD pairs, but did for daytime journey OD pairs.

Daytime journey means could not be calculated for three Finnish LFOT groups (TI -> TI, TI -> TI+GDS+SI/SA and TI, SI/SA -> TI) because the number of OD pairs was too low.

FOT	Functions		N	Distance (km)				t	p
	Baseline	Treatment		Mean, baseline	Mean, treatment	St. dev., baseline	St. dev., treatment		
FIN-LFOT	TI	TI	12	13.7	13.8	7.3	8.0	-0.202	0.844
FIN-LFOT	TI	TI, GDS, SI/SA	8	30.8	29.7	31.2	31.4	0.536	0.608
FIN-LFOT	TI, SI/SA	TI	49	19.4	20.1	13.4	12.9	-0.729	0.470
FIN-LFOT	TI, SI/SA	TI, GDS	193 (44)	22.8 (15.5)	25.0 (19.8)	31.1 (16.2)	31.9 (18.7)	-1.898 (-2.157)	0.059* (0.037**)
FIN-LFOT	TI, SI/SA	TI, SI/SA, GDS	75 (19)	16.8 (11.9)	18.3 (11.1)	17.5 (9.7)	17.8 (10.6)	-1.194 (0.763)	0.236 (0.455)
FIN-LFOT	TI, GDS	TI, GDS, SI/SA	85 (10)	16.6 (12.8)	17.9 (13.1)	18.5 (13.7)	18.7 (13.6)	-1.487 (-0.876)	0.141 (0.404)
ES-LFOT1	–	NAV, SI/SA	1174 ()	15.9 (12.0)	15.5 (11.6)	15.0 (15.4)	14.6 (15.1)	2.696 (1.311)	0.007** (0.192)
ES-LFOT2	–	DG	7819 (3778)	3.25 (2.87)	3.26 (2.88)	3.85 (3.38)	3.95 (3.41)	-0.810 (-0.213)	0.418 (0.831)
ES-LFOT2	–	TI	6447 (3217)	2.75 (2.61)	2.74 (2.62)	2.67 (2.41)	2.46 (2.35)	0.347 (-0.601)	0.729 (0.548)
UK-LFOT	–	NAV, SI/SA	291	13.2 (7.0)	13.5 (6.6)	19.4 (10.8)	20.3 (10.5)	-0.669 (1.341)	0.504 0.183
IT-LFOT	–	NAV, SI/SA	3897 ()	7.56 (5.99)	7.62 (6.06)	15.5 (12.9)	15.8 (14.0)	-0.825 (-0.629)	0.409 (0.530)
SWE-LFOT4	–	TI	265	22.4 (19.2)	22.8 (19.6)	22.9 (21.6)	23.2 (21.7)	-1.567 (-2.056)	0.118 (0.046**)

SWE-LFOT2	–	GDS, NAV, TI	1165	11.7 (8.6)	11.9 (8.7)	16.2 (11.9)	16.4 (12.5)	-1.410 (-0.306)	0.159 (0.760)
GR-LFOT1	–	NAV	414	13.5 (11.4)	13.1 (11.3)	18.3 (11.7)	17.8 (11.4)	1.362 (0.458)	0.174 (0.648)
GR-LFOT2	NAV	NAV, SI	455	13.7 (9.36)	15.5 (9.1)	18.7 (9.5)	37.2 (8.9)	-1.165 (0.802)	0.245 (0.424)
GR-LFOT3	NAV	NAV, TI	430	18.5 (14.5)	17.6 (14.9)	29.9 (22.5)	29.2 (22.4)	1.551 (-0.252)	0.122 (0.802)
GR-LFOT4	NAV	NAV, SA	543	17.8 (13.4)	17.1 (13.1)	28.5 (22.1)	23.4 (22.6)	0.894 (0.506)	0.372 (0.614)

Table 48: Mean distance between comparable OD pairs in baseline and treatment phase as well as the statistical values describing the difference. (Mean distance between comparable daytime journey OD pairs in baseline and treatment phase as well as the statistical values describing the difference.)

3.5.2.6 Night time traffic

Night time was determined to be from 6 p.m. to 7 a.m. Difference between baseline and treatment means was larger for all OD pairs than during night time journeys for most of the LFOTs. UK LFOT, Finnish LFOT with green driving support, Finnish LFOT with speed limit information/alert, Madrid LFOT with GD and TI, Greek LFOT 1 and Greek LFOT 4 had a smaller difference between baseline and treatment means for all OD pairs. In Finnish LFOT with speed limit information/alert the difference was in a different direction than for all OD pairs. However, the differences were quite small in all cases.

Spain Valladolid LFOT had a statistically significant difference between baseline and treatment means for all OD pairs. There was a statistically significant difference also for night time journeys. For Finnish LFOT with green driving support and speed limit information/alert there was a statistically significant difference for all OD pairs but not for night time journey OD pairs.

Italian LFOT, Finnish LFOT with green driving support and Greek LFOT 1 did not have a statistically significant difference between baseline and treatment means for all OD pairs, but did for night time journey OD pairs.

Night time journey means could not be calculated for two Finnish LFOT groups (TI -> TI and TI -> TI+GDS+SI/SA) because the number of OD pairs was too low.

FOT	Functions		N	Distance (km)				t	P
	Baseline	Treatment		Mean, baseline	Mean, treatment	St. dev., baseline	St. dev., treatment		
FIN-LFOT	TI	TI	12	13.7	13.8	7.3	8.0	-0.202	0.844
FIN-LFOT	TI	TI, GDS, SI/SA	8	30.8	29.7	31.2	31.4	0.536	0.608
FIN-LFOT	TI, SI/SA	TI	49 (14)	19.4 (21.4)	20.1 (19.9)	13.4 (10.9)	12.9 (9.4)	-0.729 (1.496)	0.470 (0.158)
FIN-LFOT	TI, SI/SA	TI, GDS	193 (44)	22.8 (26.0)	25.0 (27.3)	31.1 (34.1)	31.9 (32.6)	-1.898 (-0.943)	0.059* (0.351)
FIN-LFOT	TI, SI/SA	TI, SI/SA, GDS	75 (21)	16.8 (18.9)	18.3 (20.6)	17.5 (12.2)	17.8 (11.7)	-1.194 (-1.743)	0.236 (0.097*)
FIN-LFOT	TI, GDS	TI, GDS, SI/SA	85 (13)	16.6 (18.8)	17.9 (20.1)	18.5 (11.5)	18.7 (11.2)	-1.487 (-1.365)	0.141 (0.197)
ES-LFOT1	–	NAV, SI/SA	1174 ()	15.9 (14.4)	15.5 (14.0)	15.0 (17.0)	14.6 (16.7)	2.696 (1.783)	0.007** (0.076*)
ES-LFOT2	–	DG	7819 (654)	3.25 (3.93)	3.26 (4.01)	3.85 (6.46)	3.95 (6.59)	-0.810 (-1.327)	0.418 (0.185)
ES-LFOT2	–	TI	6447 (636)	2.75 (2.31)	2.74 (2.27)	2.67 (2.15)	2.46 (2.14)	0.347 (1.168)	0.729 (0.243)
UK-LFOT	–	NAV, SI/SA	291	13.2 (9.4)	13.5 (9.6)	19.4 (14.3)	20.3 (14.7)	-0.669 (-0.518)	0.504 (0.606)
IT-LFOT	–	NAV, SI/SA	3897 ()	7.56 (8.63)	7.62 (8.91)	15.5 (15.5)	15.8 (16.1)	-0.825 (-2.476)	0.409 (0.013**)
SWE-LFOT4	–	TI	265	22.4 (25.6)	22.8 (26.2)	22.9 (25.8)	23.2 (25.7)	-1.567 (-1.199)	0.118 (0.233)
SWE-LFOT2	–	GDS, NAV, TI	1165	11.7 (15.2)	11.9 (15.4)	16.2 (18.3)	16.4 (18.4)	-1.410 (-0.728)	0.159 (0.467)
GR-LFOT1	–	NAV	414	13.5 (13.7)	13.1 (12.4)	18.3 (15.1)	17.8 (13.8)	1.362 (2.502)	0.174 (0.014**)
GR-LFOT2	NAV	NAV, SI	455	13.7 (13.4)	15.5 (13.7)	18.7 (15.9)	37.2 (16.8)	-1.165 (-0.507)	0.245 (0.613)

GR-LFOT3	NAV	NAV, TI	430	18.5 (16.8)	17.6 (15.7)	29.9 (20.6)	29.2 (21.9)	1.551 (1.102)	0.122 (0.272)
GR-LFOT4	NAV	NAV, SA	543	17.8 (20.1)	17.1 (18.8)	28.5 (35.9)	23.4 (26.0)	0.894 (1.283)	0.372 (0.202)

Table 49: Mean distance between comparable OD pairs in baseline and treatment phase as well as the statistical values describing the difference. (Mean distance between comparable night time journey OD pairs in baseline and treatment phase as well as the statistical values describing the difference.)

3.5.2.7 Discussion

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 support 9.6% longer than for traffic information and speed limit information/alert in Finnish LFOT and 2.5% shorter with the bundle "navigation and speed limit information/alert" than without any functions in ES-LFOT1.

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

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

The same changes than in logger data could be seen in questionnaire data with traffic information and in Greek and ES-LFOT1 with speed limit information and navigation. ES-LFOT1 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 (ES-LFOT1) 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 LFOT 1 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 support and SI/SA there was a difference only for all journeys.

GPS logging is not faultless which is seen as outliers in the data. A systematic filtering procedure was set up and a limit of four times standard deviation was used. Nevertheless, some cases that were probably not realistic were left to data. We did not want to filter out all natural variance in the data and we trusted that the monitoring system was equally unreliable both in baseline and treatment. More observations maybe should have been filtered out. In the future studies, the filtering method should be developed further.

3.6. Road type and choice of routes

In this chapter the sixth research question of the environmental impact assessment, Env-RQ6: “Is road type and choice of routes affected?” is addressed. With this research question the hypothesis H6.1: “There is a change in choice of routes (road types)” is about to be answered with the help of the data logged during the test runs and the questionnaires.

3.6.1. Data used

In this chapter the data used for the evaluation is described in detail. Therefore the different data types and specifics of the used data are given in detail.

3.6.1.1 Data types

In Table 50 the different functions tested in the given FOTs are listed. Beneath the functions the corresponding data type and the number of subjects participating as well as the total driving kilometres in the FOTs are given where it was possible.

FOT	Function / s	Data Type	Number of participants	Total driving km
SWE-LFOT2	NAV, GDS, TI	Logged	96	653165
SWE-LFOT2	NAV, GDS, TI	Questionnaire	96	
SWE-LFOT2	NAV, GDS, TI	Focus groups	20	
FIN-LFOT	GDS, TI, SI/SA	Logged	140	344000
FIN-LFOT	GDS, TI, SI/SA	Questionnaire	140	
IT-LFOT	NAV, SI/SA	Logged	168	n/a
IT-LFOT	NAV, SI/SA	Questionnaire	168	
UK-LFOT	NAV, SI/SA	Logged	80	~300000
UK-LFOT	NAV, SI/SA	Questionnaire	80	
ES-LFOT1	NAV, SI/SA	Logged	120	n/a
ES-LFOT1	NAV, SI/SA	Questionnaire	120	
ES-LFOT2	NAV, GD	Logged	132	3249529
SWE-LFOT4	TI	Logged	554	428092
SWE-LFOT4	TI	Questionnaire	554	
SWE-LFOT1	SA, GDS	Questionnaire	54	109177
GR-LFOT	NAV, SI, TI, SA	Questionnaire	148	

Table 50: Data used for the analysis of EnvRQ6

In practice, this research question was investigated 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 51 below. It should be noted that more types exist but special types of road (e.g. ferries) 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 51: Road type descriptions by Navteq

Apparent from Table 51, Navteq classifies roads according to how fast cars travel on them, rather than common classifications as “Highway”, “rural road”, city street” etc. For simplicity “Type 0” can be translated to “Highway/motorway”, “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. For the questionnaires common names for different road categories were used.

3.6.1.2 Anticipated effect of function to be tested

It is expected that navigation will have no effect on commuting trips as one normally know the most efficient way to work/school/etc. Green driving support probably will not affect the route choice, even though a “green routing” function is included in the device. If any effects, the green routing will lead the participants on smaller roads with lower speed limits.

For traffic information the situation is a bit complicated as traffic information will not change route choice in general, but rather affect the variance, that is, the participants will choose route based on the traffic info rather than taking the same route every day.

3.6.1.3 Anticipated influence of combinations of functions

Navigation support is expected to have no effect on variation and hence any effect observed in variance could potentially be attributed to traffic information. Green driving support is expected to have limited, if any, effect.

3.6.1.4 Data selection and filtering

Data were selected from each FOT based upon the following criteria for logged data to test for differences between baseline and treatment:

- All test sites were included in the analysis except Greek LFOT
- Same origin-destination pairs were searched in baseline and treatment condition for each participant (radius = 100 m)
- All OD-pairs which have been logged at least once during baseline and once during treatment condition
- For the questionnaire data no filtering was done

For the analysis of variance, the following criteria were applied:

- Logged data were selected from each LFOT (except Greek LFOT and Spanish LFOT2 due to this data not being available at the time of analyses)
- at least 30 journeys with same origin and destination in the data (at least four both in baseline and in treatment phase)

3.6.1.5 Statistical Testing

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

In addition to this analysis of the logged data, the possible effect on variance of a road type choice due to having access a TeleFOT function was tested. In order to analyse variance, there must be a relatively high number of trips between a certain origin destination pair. Changes in variation were quantified by performing a X^2-test of independence, before and after installation, on clustered road type profiles. Clusters of roadtype profiles were computed using the k-means algorithm with k = 5 number of clusters.

3.6.2. Results

Existence of external trends, such as weather effects, that could complicate the analysis was checked. Weather is a factor that can have big influence on driving behaviour as the seasonal variation in terms of weather is big, especially in Nordic countries. Figure 27 shows a plot of weighted average road type use for all participants during the whole period of the Swedish LFOT2, and quite clearly shows that the variation is low. Consequently, no effects of external trends were found.

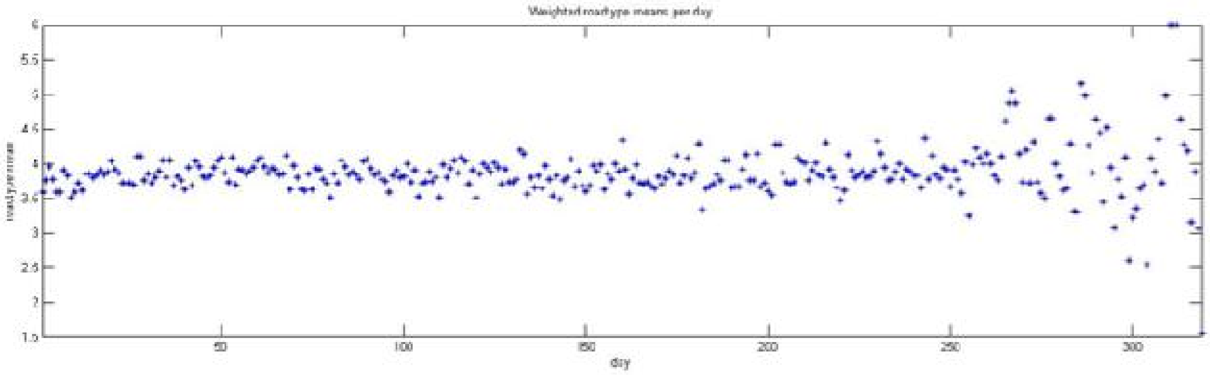

Figure 27: Weighted road type means per day, the reason for the plot getting scattered at the end is the radical decrease in number of logged trips as most participants stopped logging after 260 days, Swedish LFOT2

Significant changes in road type use were found from logged data in two of the FOTs. In the ES LFOT1 there was a decrease in use of road types 2, 3 and 5 and an increase in road types 6, 9 and 13 i.e. a shift from higher class roads to lower class roads e.g. urban streets and unpaved roads, and in the FIN LFOT there was an increase in use of road type 0, i.e. a shift from interurban and rural roads to highways (cp. 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 52). Subdividing the data to check whether factors such as gender, age, etc. were significant showed that the numbers still moved in the same direction for the analysed FOTs. Significance in the road type distribution was, however, in most cases lost when the sample size was reduced.

	FIN LFOT	IT LFOT	ES LFOT1	SWE 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 52: 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 (Table 53). Almost all non-significant cases were nowhere near the significance level (0.1). Moreover, the few truly significant 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 on sub-groups have been done on the logged data.

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
FIN-LFOT	11686	6642	7	0
ES-LFOT1	37106	27118	20	2 (10%)
IT-LFOT	4568	3551	1	0
UK-LFOT	6994	4601	6	0
SWE-LFOT2	37620	18435	59	1 (2%)

Table 53: Number of legs with significant change in route choice

The conclusion of the variance test was therefore that there were no detectable differences of variance between baseline and treatment condition for any of the LFOTs. However, the surprisingly low number of origin-destination pairs that was recorded made the analysis difficult.

Questionnaire results

For most of the functions tested the answers to the questions related to route choice in questionnaires were that there was no change. When looking at the reported change in the use of highways (Figure 28) or rural roads (Figure 29), it shows that an overwhelming majority reported "no change". For highway use over 90% report "no change" and the few that reported change did so in both directions. For the use of rural roads the results show some change in that a slight increase was reported by 10.4% of the participants due to navigation and almost as many (7.8%) due to traffic information. This seems to make sense, with navigation one sometimes gets routed on smaller roads while road signs usually route you over the main road network. Avoiding traffic jams will also route you on smaller roads away from congested highways.

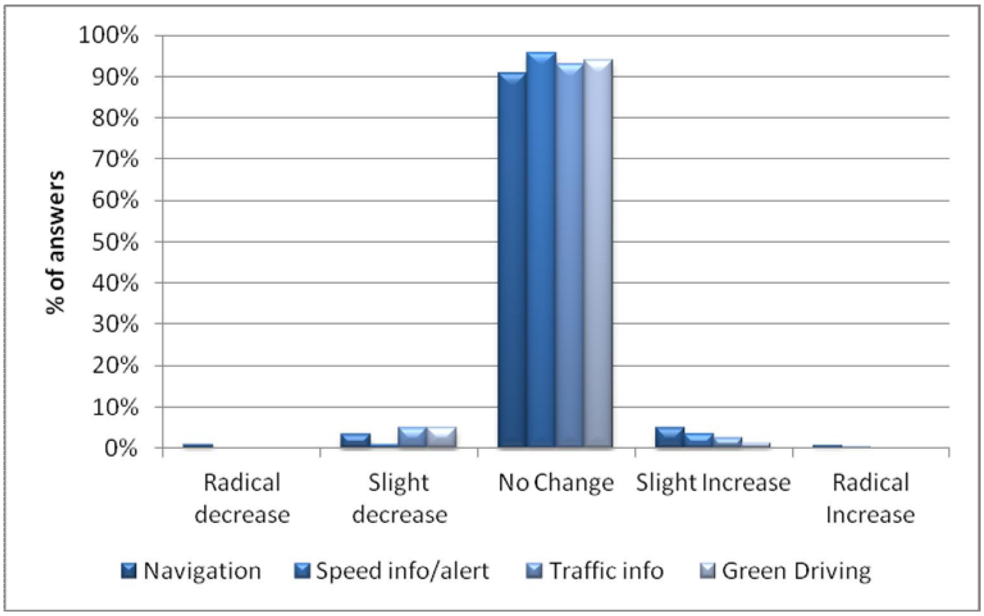

Figure 28: Change in use of highways due to having access to TeleFOT function

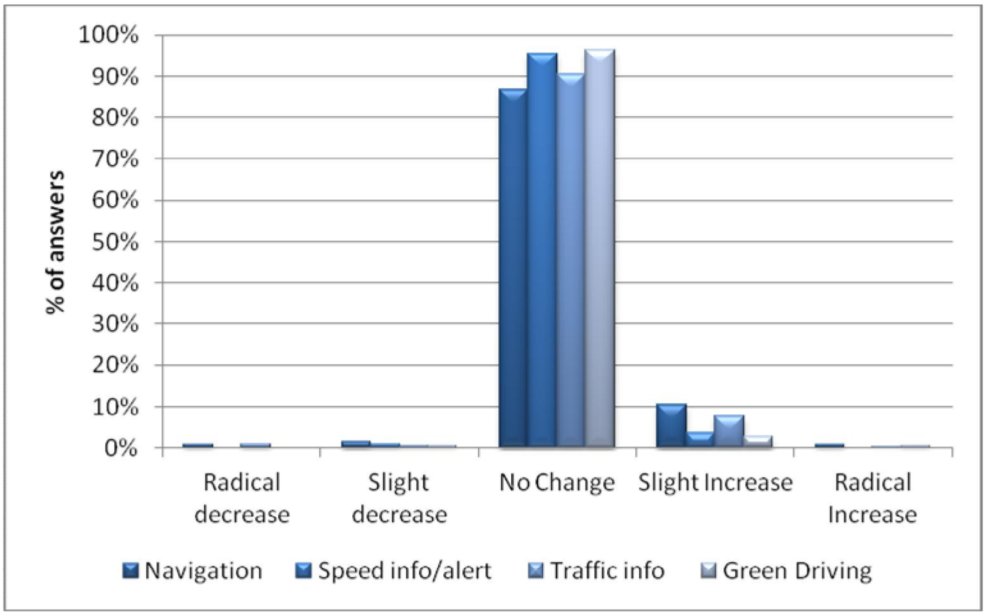

Figure 29: Change in use of rural roads due to having access to TeleFOT function

For reported change in distance driven due to having access to TeleFOT functions the results were similar for most functions with most reporting “no change” and the ones reporting change doing this in both directions (Figure 30). However, one function stood out: navigation support. For the five FOTs that tested navigation support devices, 29% of the participants reported a slight decrease (N = 450) in the distance they covered to reach their destination when using the function (ranging from 39% reporting a decrease in Greek LFOT to 16% in the UK LFOT).

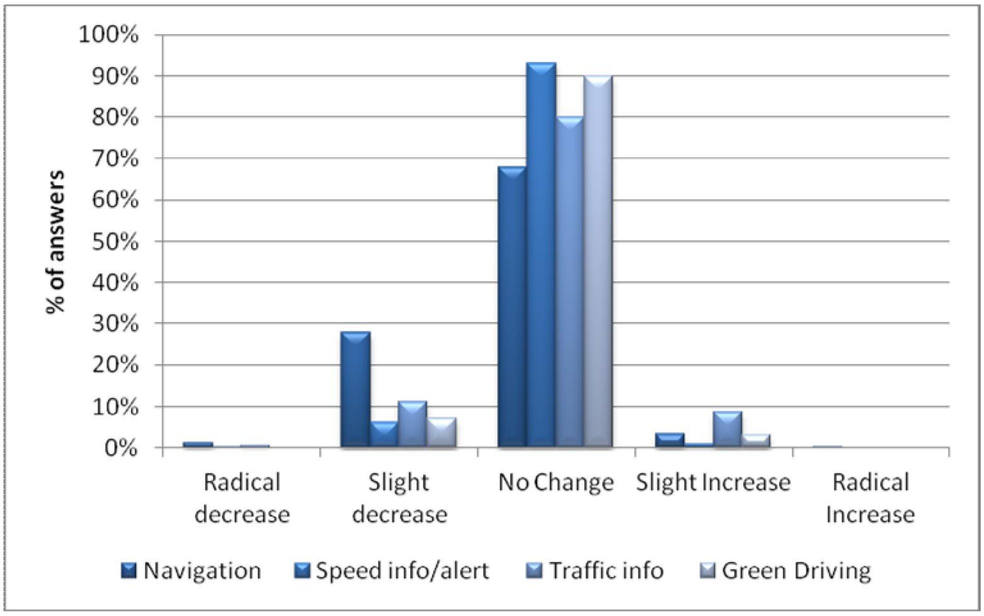

Figure 30: Change in distance driven to reach ones destination due to having access to TeleFOT function

3.6.2.1 Discussion

ES-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 for two of 20 of the tested origin-destination pairs.

One tentative explanation is that navigation support 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 them, 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) the numbers went in the opposite direction (although not significant due to much lower numbers of pairs). However, the logged data showed very small differences in distance or duration for these FOTs.

The reported distance covered to reach a destination was included to get an indication of route choice as opposed to road type choice. If you report a change in distance covered to reach a destination you must have taken a different route. Here a slight decrease is reported for many of the 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 comparatively high number of reported lowered distance to reach ones destination, relative to the logged road type proportion can be explained that it is perfectly possible to take another route, but still use the same road type mix (e.g. both routes being entirely in city streets).

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 service that was reported by the participants to be unreliable, sluggish and only showing 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 you complete your journeys faster than in the baseline condition, it is likely that you have 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.

3.6.2.2 Conclusion

The 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.

3.7. Transport mode

In this chapter the seventh research question of the environmental impact assessment, Env-RQ7: "Is transport mode affected?" is addressed. With this research question the hypothesis H7.1: "There is a change in mode of transport." is about to be answered with the help of the data logged during the test runs and questionnaire data.

3.7.1. Data used

In this chapter the data used for the evaluation is described in detail. Therefore the different data types and specifics of the used data are given in detail.

3.7.1.1 Data types

In Table 54 the different functions tested in the given FOTs are listed. Beneath the functions the corresponding Data type and the number of subjects participating as well as the total driving kilometres and the total driving hours in the FOTs are given where it was possible.

FOT	Function / s	Data Type	Number of participants	Total driving km
UK-LFOT	NAV / SA	Travel diary, Questionnaire	80	~300000
ES-LFOT1	NAV / SA	Travel diary, Questionnaire	n/a	n/a
FIN-LFOT	GDS	Travel diary, Questionnaire	n/a	344000
SWE-LFOT2	NAV / GDS / TI	Travel diary, Questionnaire	96	653165
IT-LFOT	NAV / SA	Travel diary, Questionnaire	144	n/a
GR-LFOT 1-4	NAV / SI /SA / TI	Travel diary, Questionnaire	n/a	806776

Table 54: Data used for the analysis of EnvRQ7

3.7.1.2 Anticipated effect of function to be tested

It is anticipated that static navigation will not have an effect on the mode of transport of regular journeys since people will have a predetermined route for regular journeys. For green driving support, a system that highlights the costs of driving (economically and environmentally) might push participants to use other modes of transport.

Traffic information might have the effect of either showing participants beforehand the traffic situation pushing them to choose another mode of transport in order to not get stuck in traffic. On the other hand it might also enable the participants to drive their own car to a higher extent, since they can avoid congestion easier now.

3.7.1.3 Anticipated influence of combinations of functions

Most tested devices include a combination of functions. Some combinations might work in the same direction, while some might interact with another. The different combinations of function, as well as the Greek study design where each function is introduced one at a time, might enable us to decouple the effects of the different functions.

3.7.1.4 Data selection, filtering and post processing for analysis

Data were selected from each FOT based upon the following criteria:

Travel diary data

- All but commuting trips were filtered out of the data (as defines as trips from home to school or work and back)
- Only participants who had filled in all travel diaries were included

Questionnaire data:

- No filtering has been done

3.7.1.5 Statistical Testing

Crosstabulations have been done for all FOTs with travel diaries. As the pre-dominant mode of transport in these FOTs is the car, the crosstabulations have focussed on the share of the commuting trips that is done as driver in a car.

The percentage of car travel has been calculated for each participant and period and the significance have been tested using ANOVA for repeated measures. The same calculations have then been carried out for walking, biking, and public transport.

3.7.2. Results

The results of the analysis regarding the mode of transport are shown below. Travel diary data as well as questionnaire data has been evaluated.

Cross tabulation have been done for all FOTs with travel diaries with the focus on the share of the commuting trips which are done as driver in a car since the predominant mode of transport in all FOTs is the car. The percentage of car travel has then been calculated for each participant and period and the significance have been tested using ANOVA for repeated measures. The same calculations have then been carried out for walking, biking, and public transport.

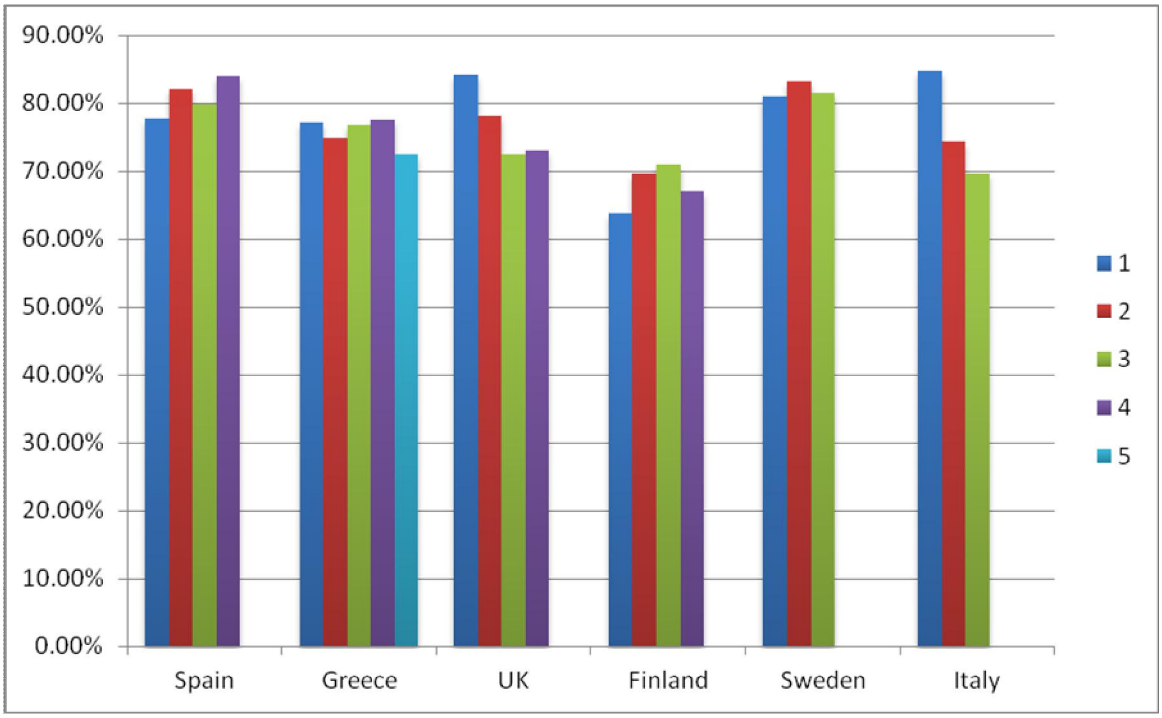

Figure 31: The amount of the commuting trips that are done by car, per FOT (all trips included). Period 1 is the baseline**.**

Figure 31 shows the amount of commuting trips that are done by car. The numbering 1-5 represents the collected travel diaries at different times. There are FOTs which collected travel diaries at three times (Sweden and Italy), FOTs which collected four travel diaries (Spain, UK and Finland) and Greece collected even five travel diaries from each participant during the FOT.

Looking at the results from the cross tabulation in Figure 31, we can see that Italy and UK (using the same device) seems to show some effect on mode of transport in terms of lower car use. However, Spain that also uses the same device has a slight increase in car driving, indicating that a further analysis is necessary. For the rest of the FOTs, effects seem to be small.

Since Italy seemed to be the test site that reported the biggest change in the use of car as mode of transport for commuting trips, the statistical analyses started there. Using only participants who had filled in the travel diary at all three occasions lowered the number of participants from 144 to 25. The result shows that the result is not statistically significant with a significance of *p*=0.366. The other modes of transport are also not significant with a significance for walking/biking (*p*=0.644) or public transport (*p*=0.288). For UK LFOT 1 doing the same analyses, the lower use of the car as mode of transport was significant (*p*=0.077). The lower car use has a corresponding increase in walking and biking (*p*=0.071). Of the 22 participants who filled in travel diaries for all periods, only one used public transport and then only for one day during the baseline period.

FOT	Change	N	*p*
IT-LFOT	(Decrease)	25	0.366
UK-LFOT	Decrease	22	0.077
ES-LFOT1	Increase	88	0.059
SWE-LFOT2	(Decrease)	34	0.676
FIN-LFOT	(decrease)	22	0.615
GR-LFOT	(increase)	56	0.581

Table 55: Change in car use per FOT

Figure 32 shows that the use of a car as the primary mode of transport for commuting trips in the UK LFOT went from 83% of the trips to under 70%. The change is statistically significant. Pairwise comparisons (as well as the graph) show that the significant change is between the baseline and the treatment phase, with little change during the treatment period.

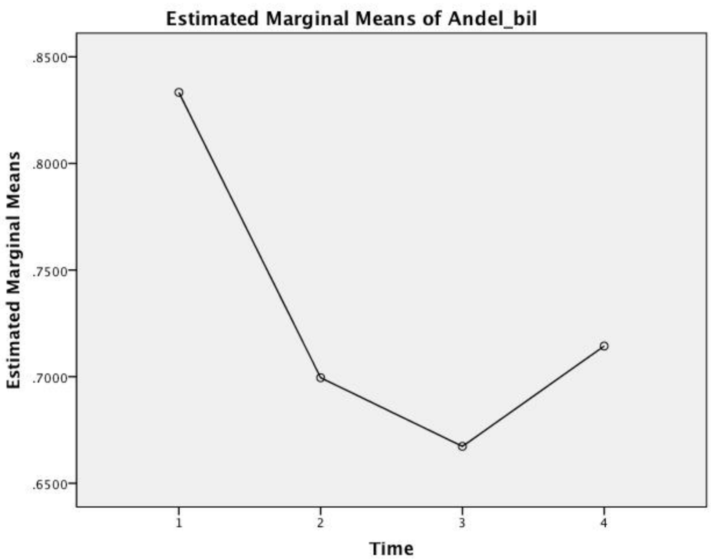

Figure 32: Estimates Marginal Means of Andel_bil

Looking at Spanish LFOT 1 data, biking and walking is significantly reduced from 26% to 22% of the commuting trips (p=0.094, N=88) while car use increased significantly (p=0.059) from about 70% to 74.5%.

For The Swedish LFOT 2, the effects are small and not statistically significant (p=0.676) in terms of car use. Walking and biking are less than one percent of the recorded trips, as were the commuting trips with public transport. Doing the same test for collective transport, it shows no significant change in the use of public transport for commuting purposes.

For Finland, no significant changes are noticed (p=0.615) using the same statistical test (cp. Figure 33).

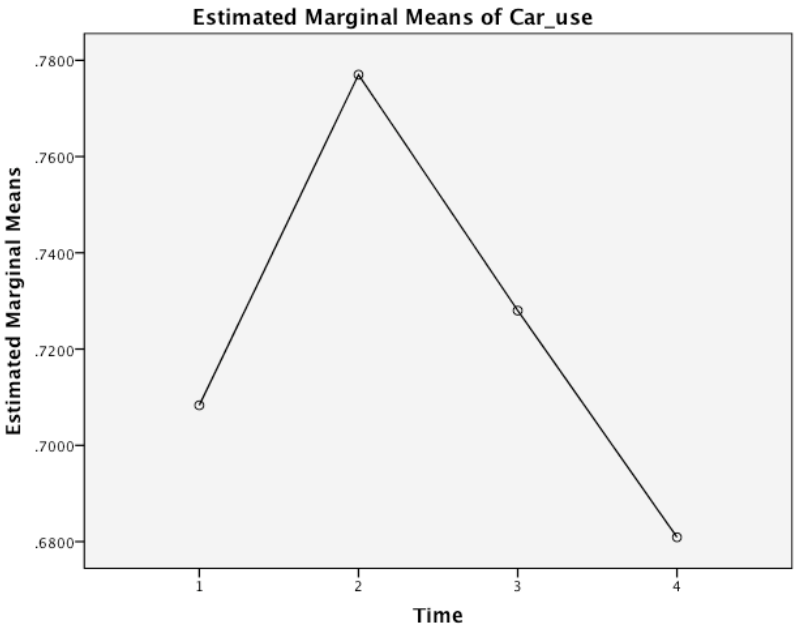

Figure 33: Finnish car use

Greece, using a different study design has to be treated differently: Since different functions were tested one at a time, it makes sense to do separate tests for each function. Therefor pairwise t-tests were done. The results are presented below:

Function	Effect	Sig. (Two-tailed)	Significant?
Navigation	Increased car use	0,526	No
Speed limit information	Decreased car use	0,580	No
Traffic information	Increased car use	0,520	No
Speed alert	Increased car use	0,506	No

Table 56: Greek car use

No significant effects on how many of the performed trips were by car could be found.

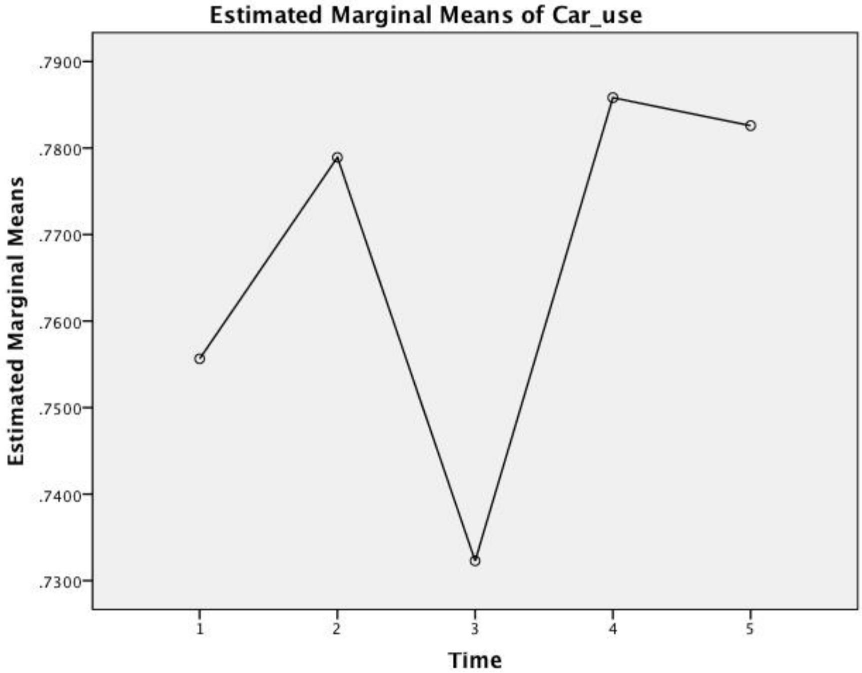

Figure 34: Greek car use

Looking at reported change of mode of transport from the user uptake questionnaires, one cannot see any trends. 96% of the participants in all FOTs report “no change” in their mode of transport due to having access to one ore more of the TeleFOT functions. The ones that reported changes were few and their answers were inconclusive.

3.7.2.1 Spread of data

The reported change of mode of transport in the user uptake questionnaires had very low spread, from 91.5% reporting “no change” (Greek FOT on navigation) to 100% reporting “no change” (Finland on speed limit information/speed alert).

For the travel diaries, the use of the different modes of transport are spread form 0-100%, with most participants using the car to a very high degree.

3.7.2.2 Contextual discussion

The significant changes in car use appeared in the UK FOT and the Spanish FOT, both using the same device. Somewhat confusing the changes were in different directions, the Spanish participants driving more and the UK participants driving less. Looking at different background variables, no explanation for this discrepancy can be seen.

3.7.2.3 Caveats

It might be a bit tricky comparing questionnaire data and travel diary data, since the analyses on the travel diaries is done on commuting trips and the questionnaire data reports on mode of transport in total. To see if this was the case, the analysis was repeated using all travel diary data. This made little difference.

3.7.2.4 Discussion and Conclusions

1. Two statistically significant changes have been found in the travel diary data. The participants in the UK FOT decreased their car use when having access to the device (speed alert and navigation support). The participants in the Spanish (Valladollid) FOT on the other hand, using the same device, increased their car use. No explanation for this surprising finding can be found in the material.
2. The post-test user uptake questionnaire gave no indication that the participants had changed their mode of transport. For Spain and UK respectively 97.5% and 99% reported “no change” of mode of transport due to having access to the device.
3. The result that UK participants report less of their journeys to be done by car in the travel diaries, but still do not report any change of mode of travel due to the TeleFOT functions in the user uptake questionnaires could be explained by change in the participants’ economic situation. During the test several participants told the researcher that they had changed their car use due to economics. One statement was, for instance: “I drive less but that is not because of the functions but because I cannot afford to drive anymore”.

The economic situation in Spain is, however not better. Still a significant increase in the proportion of trips made by car could be found. Looking at the total number of trips, on the other hand, a decrease (though not statistically significant) could be seen.

Factors that might explain the different results are (all significant differences using the chi-square test):

- Gender (Spanish participants are 71% male, UK 50%) – Looking at both groups, the increase in relative car use is bigger for the female participants than the male participants – so this must be rejected
- Reported use of navigation (72% of UK participants have used navigation less than 25% of the trips, Spain 50%). Of the ones decreasing their relative car use, a bigger proportion were using navigation, so this must be rejected as well.

- Reported use of speed alert (67% of UK participants have used speed alert less than 25% of the trips, Spain 26%): No difference were detected between the groups who used the speed alert/speed limit information for most of the trips and those who used it for less than 25% of the trips in terms of effect on mode of transport.
- Use of car (more people in Spain used car every day (76% vs. 50%), which is consistent with the higher proportion of male participants as, men in total reported more car use (74% vs. 68%).
- Use of bike/walk (UK more): men used more often the bicycle than women in total (Spanish subjects used the bike less than UK and even less with the device). There were only a couple of people reporting they walked or rode the bike regularly, so no sub-divisions could be done
- Use of public transport (UK more): women used public transport more than men (UK used public transport more and even more with the device).
- Experience as car drivers: UK reported higher experience; in total, of those who according to the travel diaries increased their relative car use, a higher proportion were experienced drivers, than in the group who increased their relative car use.

Looking at who participated in the study, with most participants driving for most of their journeys and only occasionally using other means of transport, it is no surprise that the effect of introducing these functions is quite low. Even though there were significant differences between the travel diaries in the Spanish and UK test groups, one have to conclude that the change in mode of transport must have been due to other factors than the introduction of the TeleFOT functions. The economic situation contributes to the lower proportion of car travel in the UK and the lower total number of journeys in Spain. One could speculate that the lower total number of journeys, but higher proportion of car journeys is due to a lower amount of regular journeys, such as to and from work, as these types of journeys is more ofted done by public transport.

3.8. Fuel consumption

In this chapter the eighth and ninth research question of the environmental impact assessment, Env-RQ8: “Is total fuel consumption affected?” and Env-RQ9: “Is average fuel consumption affected?” should be addressed. With this research questions the hypotheses H8.1: “There is an increase/decrease in total fuel consumption.” and H9.1:

"There is an increase/decrease in the average fuel consumption." were about to be answered with data logged during the test runs.

3.8.1. Data used

In Table 57 the different functions tested in the given FOTs are listed. Beneath the functions the corresponding data type and the number of subjects participating as well as the total driving kilometres in the FOTs are given.

FOT	Function / s	Data type	Number of participants	Total driving km
FIN-DFOT (TeleBUS)	GDS	Logger	143	475000 km
UK-DFOT2	GDS	Logger	40	
IT-DFOT	GDS, (NAV, TI)	Logger	48	907.2 km
GER-DFOT	NAV, SL/SA, ADAS	Logger	9	11400 km

Table 57: Data used for the analysis of EnvRQ8

- Finnish DFOT (TeleBus)

In the Finnish DFOT, namely TeleBus, an active real-time operating green driving application, RASTU, which guides the bus driver in driving more energy-efficiently, was tested. The study was based on logger data of 143 bus drivers collected from June 2010 till September 2011 (16 months in total). Weekends were excluded from the data used in the impact assessment. Data was divided into three categories: peak traffic, day time traffic and night time traffic according to traffic situation and time of day. Data was also split between winter and summer time. Finally, the impact assessment included data of 17590 runs for the whole route.

- UK DFOT 2

In the UK DFOT 2, another green driving support system, namely Foot-LITE, was tested in the course of a DFOT. The Foot-LITE system is a 'Smart' driving system which incorporates Green Driving Support (GDS) with safety features of Lane Departure Warning (LDW) and Forward Collision Warning (FCW).

All participants drive a fixed driving route in and around the Leicestershire area. The route encompassed three clearly defined sections of road which include only one type of road category – motorway, urban and inter-urban. The motorway section was 18.5 miles, the urban section 4.1 miles and the inter-urban section 18.3 miles long. Forty subjects participated this DFOT.

- Italian DFOT 1

In the Italian DFOT 1 there was a circular path in the urban area of Turin repeated two times for a sequential test of the functions navigation support, traffic information and green driving support. A specific road stretch (urban) of about 10.8 km was driven twice without and with green driving support. In this section the GDS is analysed regarding fuel consumption. Data of 42 subjects who participated this DFOT from October 2011 – March 2012 are available to analyse the influence of the GDS.

- German DFOT

In the German DFOT four different round trips were used in the DFOT. Every route was driven with three different configurations. The functions which were tested in Germany are: static navigation, speed limit information/speed alert, ADAS (ACC, LKA, FCW). Every driver who completed a route with each configuration has been taken into account for the analysis. In total, eight drivers fulfil these requirements and approx. 11400 km could be evaluated regarding fuel consumption.

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

- Finish DFOT: Weekends were excluded from the data used in the impact assessment. In addition, those legs with clear errors in data were excluded from the data.
- UK DFOT 2: Drivers were excluded who did not have a reference value. The amount of analysed data sets is 35 of 40.
- Italian DFOT 1: 48 subjects participated the DFOT, but for the analysis of the GDS only 42 subjects gathered the necessary data. Additional, two subjects were excluded for the analysis because of data acquisition errors.
- GER DFOT: Only drivers who completed every configuration of the route were included in the analysis.

3.8.1.2 Anticipated effect of function to be tested

Green driving support is anticipated to reduce fuel consumption significantly. The functions of the German DFOT (NAV, SI/SA, ADAS) are not influencing the driver regarding fuel consumption.

3.8.1.3 Data Selection, filtering and post processing for analysis

- Finnish DFOT: No further data were excluded.
- UK DFOT 2: No further data were excluded.
- Italian DFOT 1: No further data were excluded.
- GER DFOT: No further data were excluded.

3.8.1.4 Statistical Testing

- FIN-DFOT: T-test
- UK-DFOT2: T-test
- IT-DFOT: T-test
- GER-DFOT: ANOVA with repeated measures

3.8.2. Results

The results are divided into two sections. First the results which are based on logged data are presented followed by some additional findings from evaluating the questionnaire data of the user uptake questionnaires.

3.8.2.1 Results based on logged data

- FIN-DFOT:

The average fuel consumption on the Jokeri route varied for individual speed limit areas from 29.0 l/100 km to 54.8 l/100 km depending on season, traffic conditions and driver group. In wintertime the fuel consumption was on average 2.8 l/100 km higher than in summertime. The consumption was least in night-time traffic (39.0 l/100 km for the whole route) and highest in peak traffic (46.9 l/100km).

Speed limit	All		30 km/h		40 km/h		50 km/h		60 km/h		70 km/h	
Time of the day	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter
Night time	1.22	0.11**	2.04**	2.71*	0.02	-0.72	0.63**	-0.34**	1.72	-0.14	1.14**	-0.88**
Day time	0.48**	-0.09**	5.48	4.63**	-0.11	-0.81	0.01	-0.47	-1.86	-1.99	-1.04	-1.52*
Peak	0.50	1.80*	4.84	4.93	0.44	2.13	-0.66*	0.98	-2.07	-0.10*	0.10	1.44

Table 58: Impacts on fuel consumption (l/100 km), drivers who had been using the application from 2008/2009. Statistically significant results marked ** = p<0.05 and * = p<0.1, negative value = greater fuel consumption with the device than without it

Table 58 shows the impacts on fuel consumption for drivers who had been using the application from 2008/2009. The fuel consumption in summertime was found to be 0.5–1.2 l/100 km less over the whole route, being greatest in night time traffic when using RASTU compared to driving without it. The impact was greatest in speed limit 30 km/h area (2.0–5.5 l/100 km less with the device than without it, night time traffic results 2.0 l/100 km being statistically significant). In wintertime, the effect was not as clear. Drivers using the green driving application performed better in night time and rush hour, fuel saving being 0.1 l/100 km and 1.8 l/100 km respectively.

Drivers for whom RASTU had been activated in spring 2011 drove statistically significantly more ecologically (fuel saving 3.2–4.9 l/100 km on the whole route, Table 59) in all traffic situations when the application was active than when driving without it. The fuel saving in night time traffic was hence almost 10% of the fuel consumption for 100 km. The impact was greatest with lower speeds.

Speed limit	All	30 km/h	40 km/h	50 km/h	60 km/h	70 km/h
Time of the day	Summer	Summer	Summer	Summer	Summer	Summer
Night time	4.92	12.40	4.80**	5.28	0.67	2.20
Day time	3.46**	11.29**	3.63*	3.76	-0.92**	0.41*
Peak	3.22**	5.59	4.51*	3.64**	0.59*	2.12*

Table 59: Impacts on fuel consumption (l/100 km), drivers who had been using the application from 2011. Statistically significant results marked ** = p<0.05 and * = p<0.1, negative value = greater consumption with the device

- UK-DFOT2: The results of this DFOT show also a significant reduction of fuel consumption on the driven route (p<0.001). There is no influence if test subjects start with the baseline or the treatment as well as if the driver is female or male.

Between the baseline and the treatment 3.5% fuel could be saved on average. Nine test subjects of 35 consumed the same or more fuel during the trips while using the GDS function where all other test subjects (24) had a fuel saving from 0.34% up to 17% (cp. Figure 35).

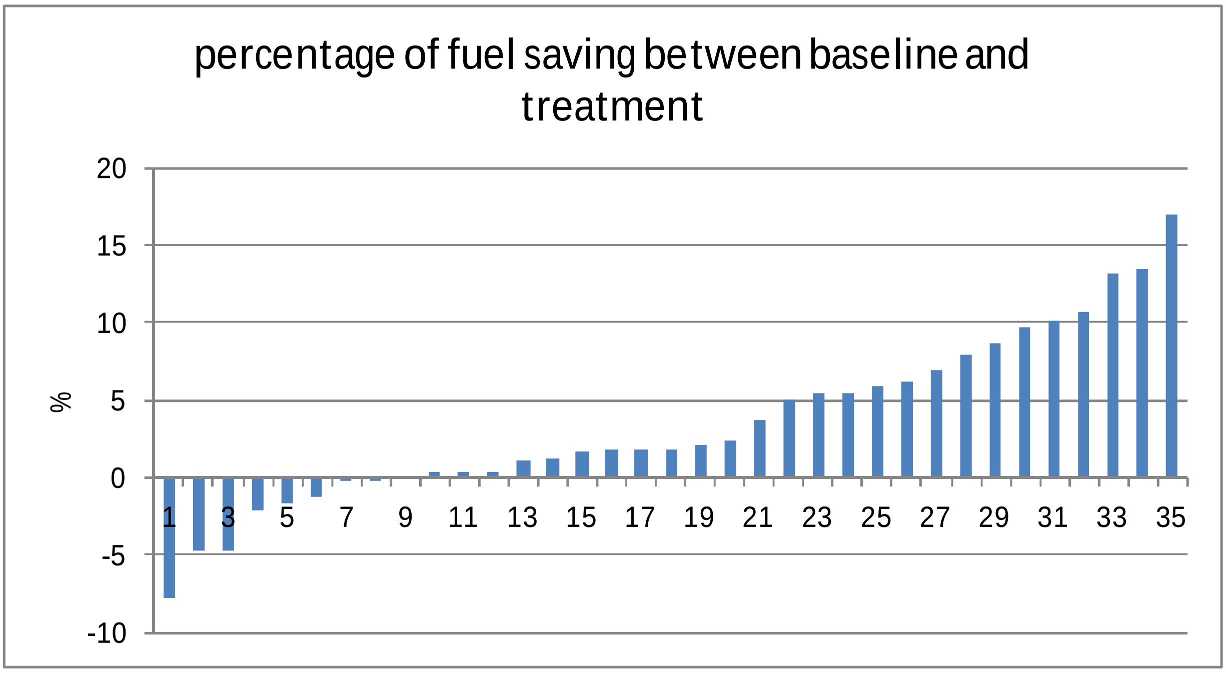

Figure 35: Fuel consumption of UK DFOT2

- IT-DFOT:

The results of the Italian DFOT show that 31 of 40 subjects (77.5%) improved their performance regarding fuel consumption. The mean improvement is about 0.026 l as a total value which is approx. 4% fuel saving for the 10.8 km section. When calculating the average fuel consumption, it drops from 5.32 l/100 km to 5.08 l/100 km. Figure 36 shows the total fuel consumption for each driver with and without the green driving support function.

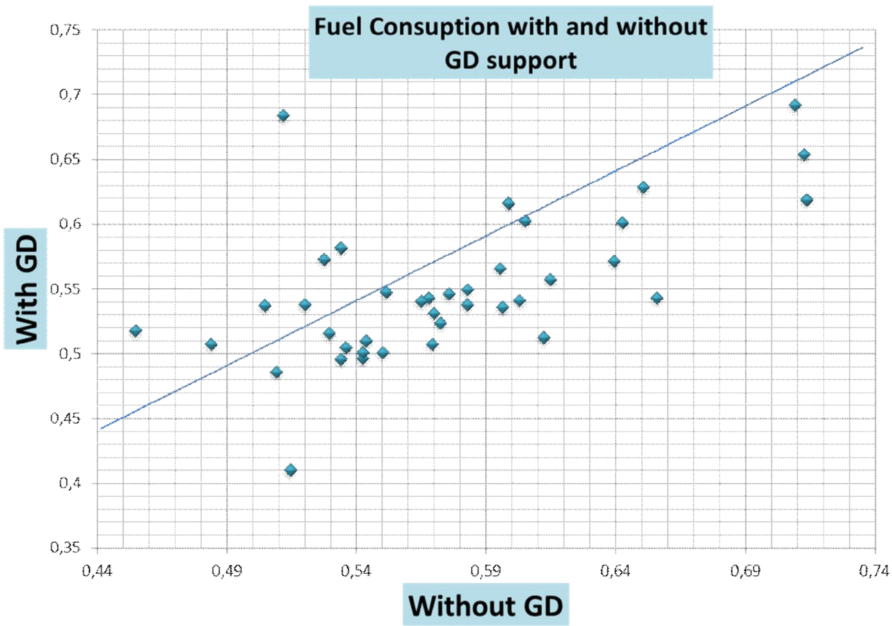

Figure 36: Italian DFOT1: Fuel consumption with and without GD support

- GER-DFOT:

In the German DFOT, speed limit information/speed alert system in combination with static navigation support has been tested. The analysis of the German DFOT was done trip by trip, i. e. all three configurations of each route were compared to evaluate the influence of the functionality of the nomadic device. The mean values of the different configurations show that there is no change in average fuel consumption caused by the functions of the nomadic device (NAV, SI/SA) (Table 60). Additionally, the statistical testing with ANOVA shows that there is no significance between the different configurations, i. e. that the bundle of functions NAV and SI/SA has no influence on the average fuel consumption.

	N	minimum [l/100 km]	maximum [l/100 km]	mean [l/100 km]	std
config A	8	8.12	10.67	9.6188	1.01114
config B	8	8.71	11.09	9.8263	.91862
config C	8	8.52	10.86	9.8850	.94396

Table 60: Min, max, mean and standard deviation of avg. fuel consumption of 8 subjects

Since no statistically significant change could be noticed with this approach, all routes have been divided into sections of same speed limits. Figure 37 shows the first route with its speed limits on the round trip.

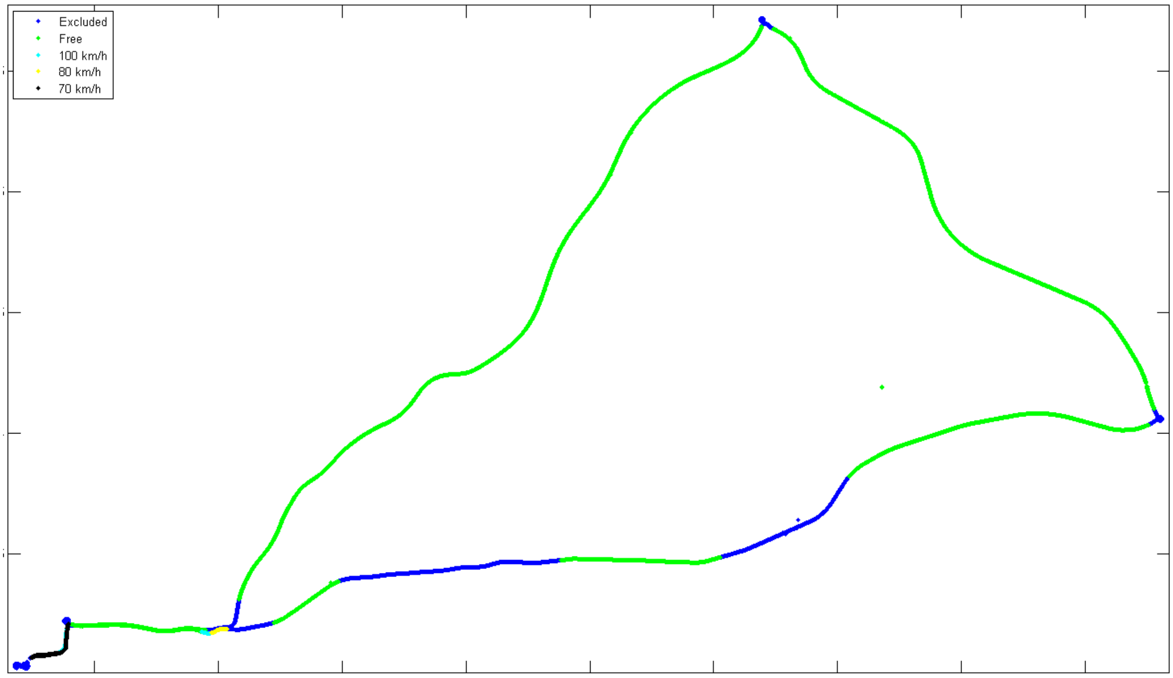

Figure 37: Route 1 with coloured sections for each speed limit

The blue sectors are excluded because of various reasons, for example, motorway exits and slip roads, areas with construction sites or sections where the speed limit on the nomadic device differs from the real speed limit on the road. All other areas which are coloured differently have been analysed. All sections of one speed limit were taken together, but the analysis showed contradictory results. There is no clear indicator that any of the tested functions in this DFOT lead to fuel saving, but neither that the functions lead to increased fuel consumption.

3.8.2.2 Results based on questionnaire data

In this chapter the answers on some of the questions out of the user uptake questionnaires are shown. With these answers the change in the view of the users on the system and its performance is shown.

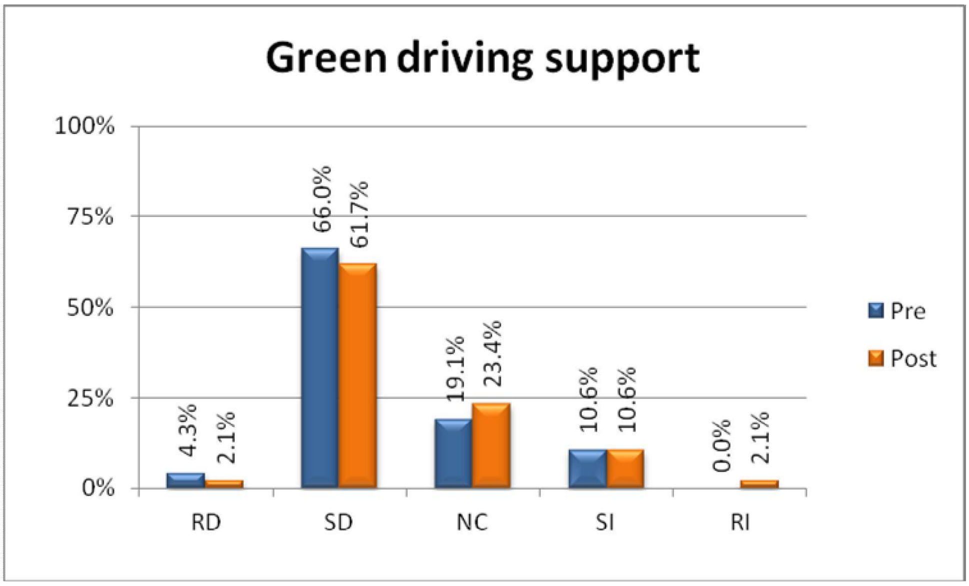

Figure 38: Answers for the question: "Do you think your fuel consumption will change with your access to the green driving support system?" (Italian DFOT)

In Figure 38 it can be seen that 66% of the subjects in the Italian DFOT assume that green driving support will reduce their fuel consumption. After the DFOT, 61.7% are still convienced of the system that it can help to reduce fuel consumption. Therewith there is a consistency between the logged data and the perception of the subjects. There might be a potential of improvement for the functions or applications to convince even more of the subjects and keep them to their decision.

At a first glance, it seems as the participants of the UK DFOT2 have a contrary opinion regarding the Foot-LITE system which has also a green driving support function. After the DFOT, the subject filled out a benchmarking questionnaire which includes one questions regarding the fuel consumption (Q3): "Do you think continued access to the Foot-LITE system would change any of the following? – Fuel used / cost of journey". 72.5% of the subjects rated that the system will lead to an increase in fuel used (Figure 39). When comparing this result to question 1a: "If your immediate rection to the Foot-LITE system was generally positive, what are the reasons given for this response?", it becomes obvious that the participants filled out the questionnaires in a wrong way. 15 of 40 participants rated that the reason for assessing the Foot-LITE system as good was: Efficiency (positive effect on fuel efficiency or journey cost) although they rated Q3 with 4 or 5 which means "increase" or "strong increase" of fuel used.

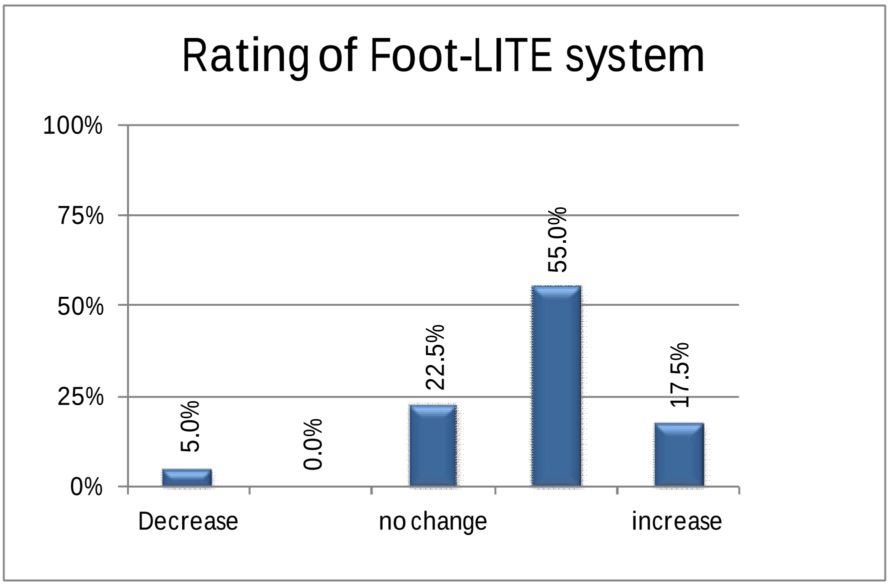

Figure 39: Rating of 40 participants in the UK DFOT2 for the Foot-LITE system regarding fuel use / cost of journey

3.8.2.3 Discussion and Conclusions

- FIN-DFOT: The main result of the study was that the use of green driving application reduces the fuel consumption significantly. When the drivers who were trained to use the green driving application in 2008/2009 had the application active their fuel consumption in summertime was found to be 0.5 – 1.2 l/100 km less over the whole route. For one section of the route the fuel saving was even significantly 4.6 l/100 km smaller than when they drove without the system.

Drivers for whom RASTU had been activated in spring 2011 drove statistically significantly more ecologically (fuel saving 3.2–4.9 l/100 km on the whole route, Table

59) in all traffic situations when the application was active than when driving without it. The fuel saving in night time traffic was hence almost 10% of the fuel consumption for 100 km.

- UK-DFOT2: This small study also shows that a green driving support system can reduce the fuel consumption significantly. Fuel savings up to 17% could be reached with an average of 3.5%. The perception of the system by the subjects was unclear since there were inconsistencies between the questions of the questionnaire.

- IT-DFOT: In Italy, 31 subjects (77.5%) improved their performance regarding fuel consumption. The mean improvement is about 0.026 l. With respect to the consumption baseline mean value of 0.575 l, a statistical significant fuel saving of about 4.5% could be achieved.

-GER-DFOT: The German DFOT with approx. 11400 km could not conclusively contribute to the research question if the functions tested in this DFOT lead to a change in fuel consumption. There is no clear indicator that SI/SA or the navigation function can help to save fuel.

Overall, it could be shown that green driving support applications, independent how they are realised, have the potential to get the driver to drive more fuel efficiently. In three different DFOTs (two with passenger cars and one with busses), a significant fuel saving of approx. 4% could be achieved.

3.9. Amount of CO_2 emissions

In this chapter the tenth research question of the environmental impact assessment, Env-RQ10: “Is amount of CO_2 emissions affected?” should be addressed. With this research question the hypothesis H10.1: “There is an increase/decrease in CO_2 emissions.” was about to be answered with the help of simulation carried out based upon the data logged during the test runs.

3.9.1. Data used

The CO_2-emissions could not be determined in the test runs because no data from the FOTs could be used to implement a TeleFOT function in the simulation. Without the simulation no statement could be given regarding CO_2-emissions since no sensor was implemented in the vehicles to measure the emmisions directly.

3.9.2. Results

It was not possible to carry out a simulation due to the limited data of the FOTs. Therefore no results with regard to the total CO_2-emissions could be determined.

With regard to the preceding research question regarding fuel consumption, it is obvious that the green driving support also contributes to a reduction of CO_2-emissions. The fuel consumption is directly linked to the CO_2-emissions and if a function leads to a reduction in fuel consumption (at least when it is distinct), it also leads to a reduction of CO_2-emissions. Due to the reasons mentioned above, these results could not be confirmed with a simulation to quantify the amount of the saving potential.

4. IMPLICATIONS TO ENVIRONMENT

4.1. Navigation

In two of the nine research questions, a possible impact of the navigation function on the environment could be identified. While average speed, speed homogeneity, speed distribution, number of journeys, transport mode, fuel consumption and CO_2 emissions were not influenced, a change in distanced travelled could be observed in the ES-LFOT1. The ES-LFOT1 used a bundle of function with navigation support and speed limit information/speed alert. Since the speed related functions would not change the distance, the change in distance must be caused by the navigation support function. The distance was 2.5% shorter with the use of the navigation device. Shorter distances to reach the same destinations are a benefit for the environment.

Furthermore in the same FOT (ES-LFOT1), it could be seen that due to navigation support the drivers increase their use of low class roads with low speed limits. Using low class roads which go through the city centers instead of using higher class roads around the city center may lead to a shorter distance, but it may also take more time if the city centers are crowded. However, at two other test sites (Italy and UK) with the same device the numbers go in the opposite direction, so if there is an influence of the nomadic device and its functions than it is really subordinate. The impact on the environment is small.

Regarding the transport mode, there are contradictory results. At two test sites (UK and Valladolid, Spain) with the same device and the same functions, an increase and a decrease in car use could be observed. Based on these findings, it can be inferred that there is no conclusion possible and the real impact is still unknown. A possible explanation for the decrease in car use might be the economical situation of the subjects since this was indicated in some questionnaires (e. g. in UK LFOT: “I drive less but that is not because of the functions but because I cannot afford to drive anymore”).

Navigation support could not show any influence on fuel consumption and therewith no influence on CO_2 emissions.

In summary, it can be stated that navigation support has a slight impact on the environment if the navigation support leads to a shorter distance to reach the destination without wasting fuel in traffic jams or on congested roads.

4.2. Traffic information

Traffic information showed potential to be beneficial for the environment in the analyses of two research questions. On the one hand, it increases the average speed on urban roads; on the other hand the subjects changed their route choice from low class roads to higher class roads which allow driving faster and more fluently. Both aspects have a positive influence on the environment.

Traffic information could not affect speed homogeneity, number of journeys, distance travelled or the transport mode.

Speed distribution might be influenced slightly, but the data could not prove this convincingly.

A statement regarding fuel consumption and CO_2 emissions cannot be given because no FOT data is available which has information about a traffic information function and a fuel gauge. It is a fact that driving between 60 km/h – 80 km/h (on rural roads) instead of 30 km/h – 50 km/h (on city roads) is more fuel efficient and therewith traffic information might have also an influence on fuel consumption, but that could not be proven with logged data from a FOT.

4.3. Speed limit information/speed alert

The speed limit information/speed alert function could only show a change in the speed homogeneity in one FOT, but it must be mentioned that only two DFOTs has been analysed regarding speed homogeneity. The data on which the analysis is based has a poor quality and therefore there is no clear implication to the environment ascertainable.

As already mention in section 4.1, regarding the transport mode, there are contradictory results. At two test sites (UK and Valladolid, Spain) with the same device and the same functions, an increase and a decrease in car use could be observed. Based on these findings, it can be inferred that there is no conclusion possible and the real impact is still unknown. A possible explanation for the decrease in car use might be the economical situation of the subjects since this was indicated in some questionnaires (e. g. in UK LFOT: "I drive less but that is not because of the functions but because I cannot afford to drive anymore").

On no other parameter of the environment (e. g. average speed, number of journeys or fuel consumption) an influence of the function is detectable, so that no statistically significant environmental impact of this functionality could be assessed or derived from the results gained in this project.

4.4. Green driving

The green driving application which is primary developed to save fuel and therewith reduce emissions shows its potential in three FOTs in this project. The reduction of fuel consumption was determined in the Finnish, Italian and UK DFOT. This reduction was statistically significant with an average of around 4%. Also to reduce fuel, the smaller variance of the speed distribution can contribute. These results show obviously the positive implication of the green driving support to the environment.

In the Finnish LFOT the function pair traffic information and green driving support was compared to the function pair traffic information and speed limit information/speed alert. The result was that the distance travelled was 9.6% longer when using green driving support as the second function compared to speed limit information/speed alert as the second function. A longer distance might be a negative impact on the environment in some cases, but a slightly longer route instead of a congested shorter route has a positive impact on the environment. The data of the central database can be analysed more specific in a further project to point out the reasons for such phenomena. The longer distance might occur due to logging errors, change of route for driving to the same destination or an aberration from the route due to a wrong driving manoeuvre. Since only one FOT could identify a change in distance, it is vague to state that as a possible negative implication to environment.

As opposed to this, the result of saving fuel by using the green driving support system was determined in three FOTs and therewith attests an impact on the environment.

5. DISCUSSION AND CONCLUSIONS

In this report the background of the TeleFOT study is described and results from other projects are presented. With these results a suitable approach to evaluate the environmental impacts of the functions has been elaborated.

After this the methodology of the different large scale and detailed Field Operational Tests for the environmental impact assessment has been described. Additionally, the data which has been gathered during the FOTs is presented.

Subsequent to the description of the methodology the results gained from the data assessment are presented per research question, test site and functionality or combination of functionalities. Where it was possible or needed these results were interpreted to explain the cause and meaning of the results.

At the end the results and therewith the impact on the various research questions in the environmental impact assessment are condensed per function tested in this study.

Finally a conclusion of the results mentioned in this deliverable must be drawn. From four tested functions three (navigation support, traffic information and green driving support) showed an implication on the environment in different manners.

First of all, green driving support which was designed to help the driver to drive in a more economic and fuel efficient way, shows a huge impact on fuel efficiency. The FOTs which tested this function had the opportunity to log the fuel consumption directly and therewith they provided a good data quality to evaluate the impact of this function. The average fuel saving was about 4% compared to the baseline condition. With regard to the society, a single application on the navigation device or a smart phone can easily contribute tremendously to a more fuel efficient driving (if the advice is not ignored or disregarded by the driver) and along with this to lower CO_2 emissions.

The traffic information function could show its benefit to the environment when guiding the driver from low class roads onto higher class roads which have higher speed limits and a more fluent traffic flow. As already mentioned in chapter 1.3 the optimal ratio between driving speed and fuel consumption is between 60 km/h – 80 km/h. So, the benefit for changing from low speed roads to high speed roads is obvious.

If shorter journeys are beneficial for the environment or not, needs a closer review. Shorter journeys are beneficial if the absolute fuel consumption of the journey is less compared to the original, longer journey. The opposite is true if the journey is shorter, but due to slow moving traffic for instance, the absolute fuel consumption is higher. This must be considered when drawing a conclusion about the impact of the navigation function on the environment. With the available information, a final statement can not be given for this function.

When talking about the benefit not only for the driver himself, but for the whole society, every function which saves fuel and therewith emissions, contributes to one big objective: to reduce as much emissions as possible. This societal value is clearly identified for the above mentioned functions and therewith a really valuable outcome of this project.

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ANNEX I – TESTED DEVICES

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

UK DFOT2&3

The UKDFOT2 and UKDFOT3 utilised the Foot-LITE system which is a ‘Smart’ driving system which incorporates Green Driving Support (GDS) with safety features of Lane Departure Warning (LDW) and Forward Collision Warning (FCW). Foot-LITE provides the driver with feedback and information on Smart driving behaviours in the vehicle, in real time via an integrated visual interface presented on a Smartphone (HTC HD2).

German DFOT

The German DFOT uses two sources of driver support which are functions of the nomadic device and advanced driver assistance systems which are implemented in the vehicle. The nomadic device provides three functions to the driver: static navigation, speed limit information and speed alert. The advanced driver assistance systems were adaptive cruise control (ACC), lane keeping assist (LKA) and forward collision warning (FCW). This DFOT was used to analyse the influence of combining build-in functions with a nomadic device.

ES-DFOT1

In the ES-DFOT 1, the navigation device NDrive G800 with specific logging capabilities was used. The functions which were studied in this DFOT were: navigation support (static), speed limit information and speed alert.

Italian DFOT

The purpose of this study was to evaluate a PND providing a standard navigation function and two additional functions implemented on the same device. The two additional functions were green driving support and traffic information.

Finnish DFOT (TeleBUS)

In TeleBUS DFOT, the impacts of a green driving application were assessed in city bus traffic. Specifically, the purpose of the study was to assess the impacts on fuel consumption, speeding and passenger comfort. The green driving function tested in TeleBUS was the active real-time operating green driving application RASTU developed in VTT since 2004. RASTU guides the bus driver to drive the more energy-efficient (or fuel-efficient) way. The system includes location information and it has the information on the bus route and timetable. The system guides drivers in economical driving, taking into account the quality of service, vehicle position compared to the scheduled position and the passengers' traveling comfort.

Finnish LFOT

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

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

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

Greek LFOT

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

Italian LFOT

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

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

Spanish LFOT1

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

Spanish LFOT2

The Spanish LFOT2 was based in the city of Madrid. One of the peculiarities of the Spanish LFOT2 was that all the participants of the FOT were professional drivers recruited among the clients of the device provider company (Crambo) that were already using the basic Vexia device (nomadic device). This device only provided navigation support to the users while during the FOT execution the drivers where provided with an enhanced version of the device providing navigation + green driving support for one of the FOT drivers group and navigation + traffic information to the other FOT group.

Swedish LFOT1

In the city of Stockholm all vehicles belonging to the city should be fitted with a device that made the drivers drive more eco-friendly, and not exceed speed limits. Therefore a nomadic device with two functionalities was used during this FOT. Firstly the device shows the current speed limit and warns if you pass it (speed limit information/speed alert). Secondly it gives you green driving support in the form of one acceleration-deceleration bar and a score. In addition there is a web page where you can see the total score and some related data for all the cars in the car pool.

Swedish LFOT2

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

Swedish LFOT4

The Swedish LFOT4 tested an Android based smartphone with an application called Trelocity. This application gives traffic information to the driver which is in detail suggesting routes and giving him the travel times to the destination.

UK LFOT

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

ANNEX II – STATEMENT OF PRINCIPLES REGARDING DATA-SHARING FOLLOWING TELEFOT

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

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

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

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

- Third-parties (for example national organisations) who have supported the collection of the data within the TeleFOT project will be given access to the aggregated LFOT data on written request.
- Third-parties who are not affiliated to the TeleFOT will not be given automatic access-rights to TeleFOT data but may apply for specific analyses to be conducted on their behalf. If analyses are required once the project has been completed, an application should be made to the TeleFOT Project Co-ordinator

in the first instance who will pass the request on to an appropriate partner (for example, Impact Assessment WP Leaders).

- A charge may be made for analyses of the data if requests are made once the project has been completed.
- The European Commission may wish to sub-contract further analyses of the combined data to one or more of the partners (for example Impact Assessment WP Leaders) to support future policy and decision-making. The financial support for this work will be agreed outside the arrangements for TELEFOT.

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

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

Security

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

Consent

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

Publication

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

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