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Impacts on environment – Preliminary results

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SEVENTH FRAMEWORK PROGRAMME

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LIST OF ABBREVIATIONS

ABBREVIATION	DESCRIPTION
CAN	Controller Area Network
D	Deliverable
DoW	Description of Work
DFOT	Detailed FOT
GPS	Global Positioning System
FOT	Field Operational Test
LFOT	Large Scale FOT
ND	Nomadic Device
OBD	On board diagnostics
PDA	Personal digital assistant
PND	Personal navigation device
RQ	Research Questions
WP	Work Package

REVISION CHART AND HISTORY LOG

REV	DATE	AUTHOR	REASON
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0.2	07/04/2011	Pontus Engelbrektsson Maria Henar Vega Ulrich Schröder	Description of evaluation approach and first results per Research Questions
0.3	27/09/2011	Ulrich Schröder	Insert explanatory notes of the peer reviewers
0.4	07/05/2012	Devid Will	Insert results
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1. INTRODUCTION

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

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

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

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

The analysis undertaken within the TeleFOT project aims to assess the impact of aftermarket nomadic devices in five distinct assessment areas; Safety (WP4.3 leader LOUGH), Mobility (WP4.4 leader VTT), Efficiency (WP4.5 leader CERTH/HIT), Environment (WP4.6 leader IKA) and Business Models for User Uptake (WP4.7 leader CHALMERS). In order to measure the impacts, SP2 in collaboration with SP4 has developed core research questions and hypotheses for each assessment area that also take into account the functionality of the devices specifically under consideration in TeleFOT.

This Deliverable D4.6.2 deals with preliminary results of the environmental impact assessment. Therefore the progress made so far since the development of the analysis plan in D4.6.1 is described in this deliverable. To get to the first preliminary results further steps have been carried out to address the defined research questions of TeleFOT. These steps contain the definition of the needed data in form of performance indicators and the needed format and scripting for the central database used for the evaluation inside the TeleFOT project. A description of these steps is provided in the following sections of the deliverable.

The preliminary results of this deliverable are based on the available data, which has been post-processed on the central database. The data comes from first conducted LFOTs of the project, which have been finalised. Additionally data from the TeleFOT DFOTs have been used, which are almost finished or even have been finished.

A report on the pilot analysis undertaken in WP 4.6 will be given in the deliverables following D4.6.2 and in the final deliverable D4.6.3.

2. Executive Summary

In this deliverable D4.6.2, the concept for the assessment for the environmental impact is presented. Two different approaches for the evaluation, a direct and an indirect approach, are described. Additionally the research questions that are about to be observed in the environmental impact assessment, are given.

The evaluation approach is described for every research question in detail in the deliverable. The collected data used to evaluate the research questions is specified and a description of the type of data used in the first preliminary evaluations is given. The research questions and the hypotheses observed in the evaluation are described more in detail.

First results based on questionnaire data, travel diaries and logged data are shown in this deliverable. The statistical testing could partly approve statistical significant changes when comparing baseline condition with the treatment phase.

For the indirect approach, first data of the German DFOT has been analysed, but no statistical significant changes in driver parameter like safety need, desired velocity or compliance with speed limits could be noticed. Only, if a real change in driving behaviour can be figured out from the FOTs, traffic simulation will also show a change.

The next step which is currently on-going is to analyse more FOTs to answer each single research question sufficient and to get an overall understanding of the influence of each function in the environmental impact area.

3. Concept of Environmental impact assessment

In the environmental impact assessment different impacts, like harmful substances, noise or the impact on other traffic participants can be evaluated. However the focus inside the TeleFOT project lies on the evaluation of the impact on emission of harmful substances. These emissions can contain gases like CO, CO_2, NO_X, SO_X and NMHS.

To calculate the impact the use of the system will have on the driver, several different approaches can be made.

The first approach is to determine the emissions directly, by measuring these emissions inside the car during the test runs. Due to the amount of vehicles used in the TeleFOT project and due to the fact that most of the vehicles are owned by the test subjects themselves, an equipment of the used cars with the needed measuring devices is not feasible.

In the second approach the emissions can be determined indirectly. This can be done by calculating the emissions from measured fuel consumption inside the car, which can be gathered by sensors already installed inside the vehicle, or by means of traffic flow simulation. During the simulation the fuel consumption and the emissions can be determined by calculations based upon a detailed vehicle model, containing information about the drive train and driver behaviour.

A direct evaluation of the emissions emitted by the test vehicles can only give answers to the influence on the test vehicle and the driver itself but cannot answer questions on the influence on the surrounding traffic. These influences can be achieved by traffic flow simulations. Therefore the environmental impact assessment in TeleFOT includes the indirect evaluation approach using traffic flow simulation.

In WP 4.6 a total of initially 13 research questions are addressed (see Table 1 below). Research question 1-7 will be answered by data from vehicle data loggers and gathered directly inside the FOTs. With these data the research questions 8-13 will be used to determine the influence of the systems on the driver behaviour and by this on the environment.

The influence on the research questions 8-13 will be answered by means of a combination between the evaluating of logged vehicle data and an evaluation based on traffic flow simulations. Within the simulations the necessary parameters, like e.g. fuel consumption, can be determined for each vehicle inside the traffic environment individually. The individual data are available not only for the equipped vehicles inside the traffic flow, but also for the unequipped vehicles. This data allows evaluating not only the environmental impact for a single vehicle but also globally for the traffic network based upon the penetration rate of the functions.

In [DOR03] and [MIT03] the different factors of influence on fuel consumption are introduced. These factors are driving behaviour, traffic environment, route and vehicle properties. In [UMW01], [UMW03] and [VAN00] it is shown that the driving style has an important impact on fuel consumption which is in the range of 10%.

In this project only the factors that can be influenced by the driver, like route, traffic environment and driving behaviour, are examined. Vehicle properties, like the mass, the shape, the engine or the transmission ratio of the vehicle, cannot be influenced by the ND and therefore will not be evaluated.

E-RQ1 to 3 Is speed affected?

According to [GRE00] restrictions of speed can lead to savings of up to 40 % of fuel with an accompanied increase of travel time of 12 %. [UMW06] name the fuel saving for driving at adjusted speeds being 15 %.

E-RQ1 to 3 Is acceleration affected?

[RIE99] is also addressing the influence of acceleration and deceleration on fuel consumption. For both cases, the acceleration and deceleration, the possible savings are given with 5 to 15 %. In [REI98] the potential of fuel saving by avoidance of inefficient deceleration, wrong freewheeling

Strategy and lack of anticipatory driving is determined to be up to 30%.

E-RQ4 and 5 Is the character of trips affected?

With increasing length and number of trips the fuel consumption can be scaled up to this increase.

E-RQ6 Is the road type and route affected?

In [RIE99] the influence of the choice of route is described. Herein the effect of the change of route chosen is stated with 5 to 10 %. In [KAM99] the savings of an optimal route choice are around 5 %. [REI98]

E-RQ7 Is choice of transport mode affected?

The choice of transport mode has an effect on the fuel consumption, at least the fuel consumption can be eliminated in case the driver chooses to walk by foot or to go by bicycle. The use of other transport modes like buses or trains is also affecting the fuel consumption, even if the effect cannot be indicated numerically.

E-RQ8 and 9 Is fuel consumption affected?

The fuel consumption can be measured directly or determined by simulation of the vehicle drive train described in [KIT06]. With this parameter the emission of CO_2 can be calculated.

E-RQ10 and 11 Is the amount of emissions affected?

The amount of emissions is affected by the determined fuel consumption. The simulation of the drive train calculates the emissions of CO and CO_2 according to an engine map, in which the emissions for every working point of the engine is deposited [NEU03].

E-RQ12 and 13 Is the traffic environment affected?

In [WEI00] the effect of ADAS is examined with the help of traffic flow micro-simulations. With this simulation the effect on a single vehicle as well as the effect on a traffic environment with regard to the system penetration rate can be determined. In [MET98] a fuel saving of about 20 % can be achieved by avoiding congestions. In [PIO99] the optimal ramp metering can lead to savings about 5%.

Beneath the general assessment of the Research questions in WP 4.6 each research question is about to be assessed with regard to varying background parameters, like gender, age, experience etc. or by changing impacts, e.g. road types or speed limits (see Table 1 and Table 2).

Background variables the results will be explained by	E-RQ 1 Is average speed affected?	E-RQ 2 Is speed homogeneity affected?	E-RQ 3 Is speed distribution affected?	E-RQ 4 Is the number of journeys affected?	E-RQ 5 Is the distance travelled affected?	E-RQ 6 Is road type and choice of routes affected?	E-RQ 7 Is transport mode affected?	E-RQ 8 Is total fuel consumption affected?	E-RQ 9 Is average fuel consumption affected?	E-RQ 10 Is amount of CO-emissions affected?	E-RQ 11 Is amount of CO_2-emissions affected?	E_RQ 12 Is the use of the system influencing other traffic participants?	E_RQ 13 Is the use of the system influencing traffic surroundings?
Gender, age	x	x	x	x	x	x	x						
Ownership of the car	x	x	X	X	X	X							
Visual and hearing aid							X						
Total annual kilometres, driving experience	X	x	X	X	X	X	X	x	x		x	x	
Road type driven	X	x	X		X	X							
Driving style	X	x	X			X							
Speeding	X	x	X			X		x	x		x	x	
Incidents	X	x	X			X							
Use of transport modes	x			X			X						
Previous familiarity with devices and functions	x	x	x			x							
Opinions	x	x	x	X	x	x	x						

Table 1. Assessed background variables per Research questions

Impacts will be analysed by	E-RQ 1 Is average speed affected?	E-RQ 2 Is speed homogeneity affected?	E-RQ 3 Is speed distribution affected?	E-RQ 4 Is the number of journeys affected?	E-RQ 5 Is the distance travelled affected?	E-RQ 6 Is road type and choice of routes affected?	E-RQ 7 Is transport mode affected?	E-RQ 8 Is total fuel consumption affected?	E-RQ 9 Is average fuel consumption affected?	E-RQ 10 Is amount of CO-emissions affected?	E-RQ 11 Is amount of CO_2-emissions affected?	E_RQ 12 Is the use of the system influencing other	E_RQ 13 Is the use of the system influencing
Road type	x	x	x			x							
Speed limit	x	x	x					x	x		x	x	
Having access to system													
Actual use of system	x	x	x	x	x	x							
Function	x	x	x	x	x	x	x	x	x		x	x	
FOT/Community	x	x	x	x	x	X	x						

Table 2. Assessed impacts per Research questions

In the following chapters a more detailed description of the evaluation methodology of the research questions inside WP4.6 and conducted pilot test analysis are given.

4. E-RQ 1 Is average speed affected?

4.1. Data

The data which have been used to answer this research question comes from the German DFOT (GER DFOT) and the UK DFOT studies 2 & 3.

The UK DFOT studies 2 & 3 were specifically designed to help evaluate this RQ by splitting the driving scenario into three clearly defined sections of road which include only one type of road category – Motorway, Urban and Inter-urban (cp. Figure 1). The motorway (aka freeway, autobahn etc) section consisted of 3 or 4 lanes with a speed limit of 70 mph, was 18.5 miles 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, at 4.1 miles 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, 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 in length. As can be seen in Figure 1 the trial started and finished at 'MIRA', with the period of driving until the beginning of the motorway section reserved for the participant to get used to the test vehicle and in the experimental condition the Smart driving advisor (the Foot-LITE system offers both green and safe driving feedback via an integrated in-vehicle display). The final section from the end of inter-urban to MIRA was again excluded as the final workload questionnaire had already been completed and speed limits dropped to 30 mph with traffic densities increasing. Average speed data were also assessed for the entire journey, i.e. from the beginning of the motorway to end of the inter-urban sections. Participants completed the driving scenario on two separate occasions (separated by one week, but on the same day and at the same time of day to attempt to limit external factors such as traffic), one a control (no Smart driving feedback offered) the other where feedback was offered.

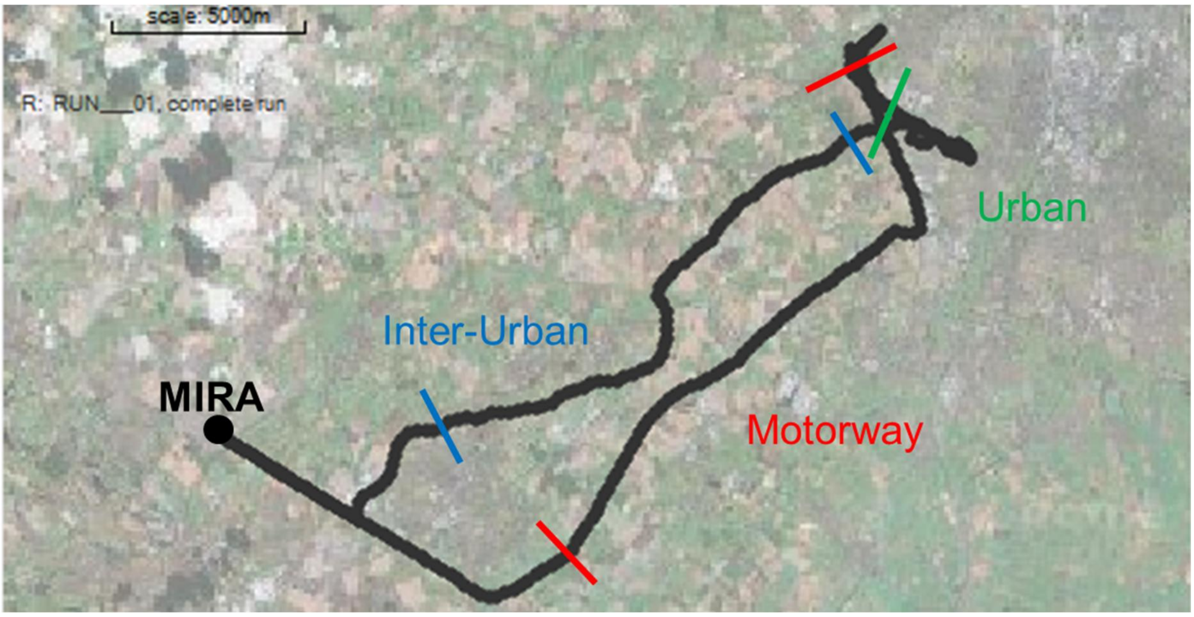

Figure 1. Driving route selected for UKDFOT2

The UKDFOT3 trial followed a similar setup to UKDFOT2, again with three defined sections of roadway (sequence: Inter-urban, Motorway and Urban). However, this driving scenario was generally shorter taking approximately 13, 6.25 and 5.5 minutes (respectively) to complete; again with sufficient time before data collection began for drivers to familiarise themselves with the forward collision warning (FCW) and lane departure warning (LDW) system. Participants completed two laps of this scenario; one was used as a control where no feedback was given, the other where feedback was offered to the driver. The order the conditions were randomised, but were completed in the same session one after the other.

With GER DFOT1 four different driving routes were selected using various road types, with average speed for the entire journey being presented. Drivers were presented with either: Only speed information and speed alerts (via a Satnav system); SI/SA plus ADAS; or just ADAS.

The following criteria to exclude data from those DFOTs were applied:

- UK DFOT2: Drivers were excluded who did not have values for both the experimental and control conditions. This reduced number from 40 to 35.

- UK DFOT3: Drivers were excluded who did not have values for both the experimental and control conditions. This reduced number from 23 to 19.
- GER DFOT1: Drivers were excluded who did not have a full set of data i.e. no data for each configuration. This reduced number to 8 participants.

4.2. Average Speed

UKDFOT2: Results showed no significant difference in average speed between the control and experimental (Foot-LITE; Eco and Safe driving in-vehicle feedback) conditions for either the journey as a whole or for the individual road sections. Data presented in Figure 2 could suggest a very small decrease in average speed when using the Foot-LITE system during motorway driving, and an equally as small increase in urban driving (both non-significant at p=0.160 and p=0.176 respectively).

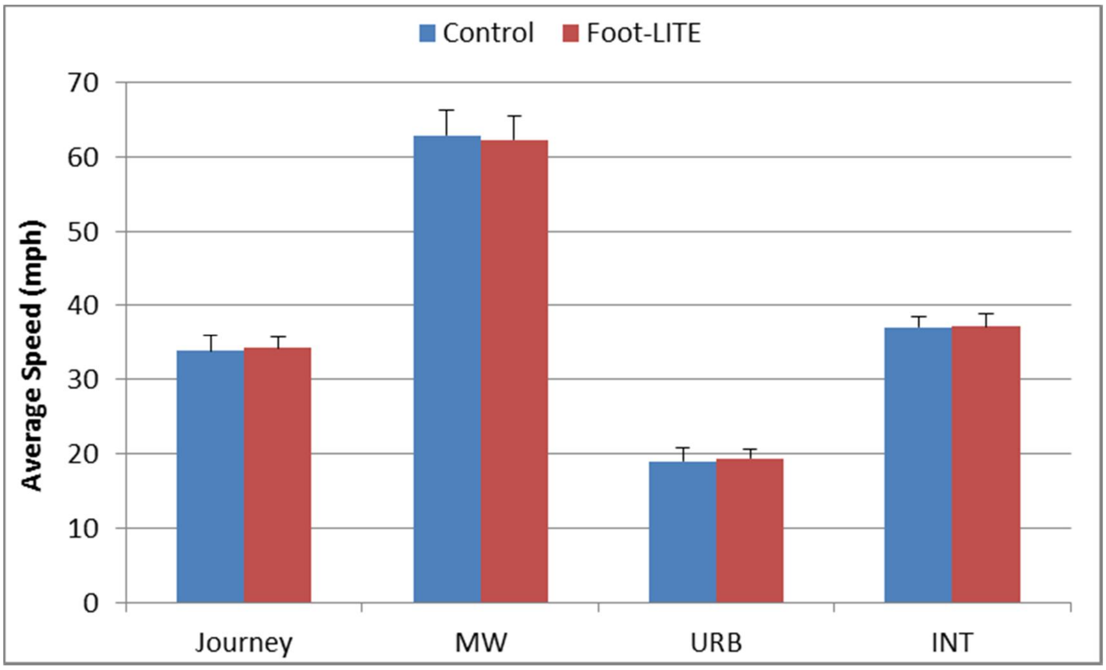

Figure 2. Average Speed data from UKDFOT2. Error bars represent the standard deviation of the mean data

UKDFOT3: Again results show no significant difference in average speed when using the Mobileye system (FCW and LDW) for the three different road types (cp. Figure 3).

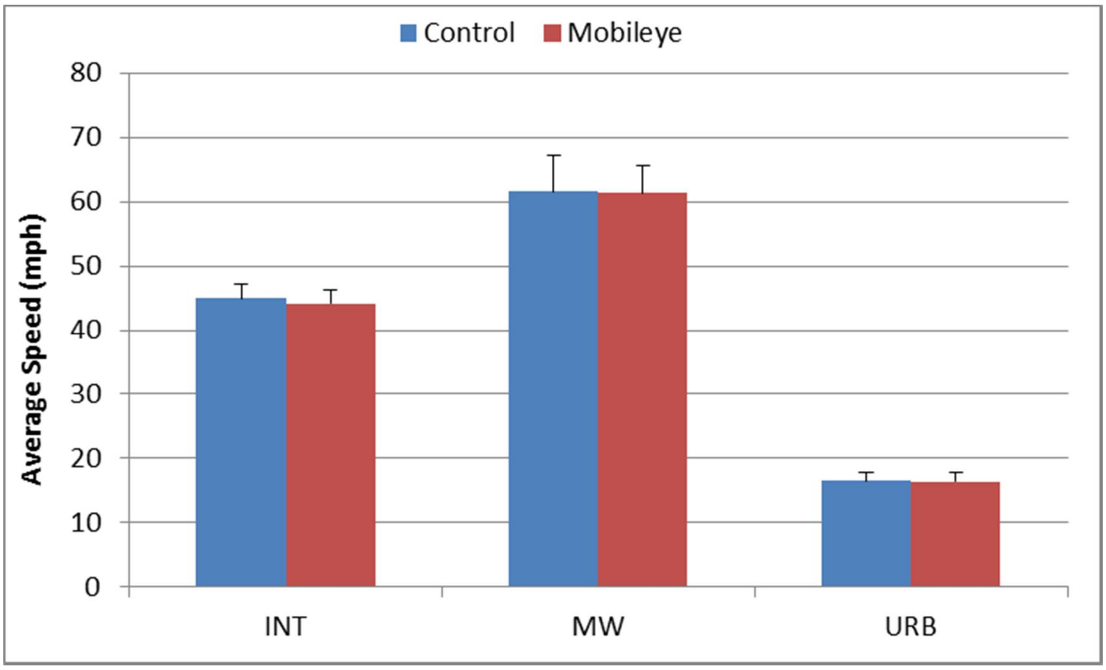

Figure 3. Average speed data from UKDFOT3. Error bars represent the standard deviation of the mean data

GER DFOT1: 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 alert systems (cp. Figure 4).

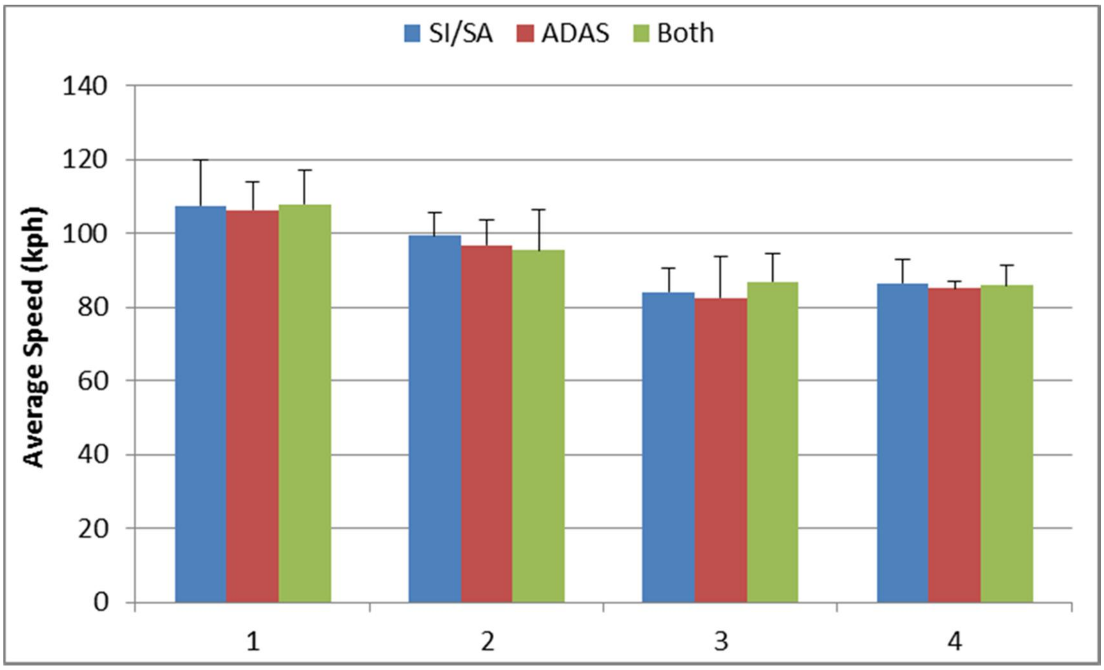

Figure 4. Average speed data from GER DFOT1. Error bars represent the standard deviation of the mean data

The standard deviations of the mean values for each participant with respect to average speed are presented as error bars on the histograms.

4.3. Discussion

Results from UKDFOT2 (cp. Figure 2) showed that no differences were observed 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 major criticisms 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 study has shown 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.

As stated in the results, UKDFOT2 could suggest a non-significant (not even a strong trend) increase in average speed when driving with the GDS system in the urban scenario of 2% compared to the control condition. As well as this possibly being due to any number of external factors, it could be consistent with the aims of the system. Green driving in this context does not aim to slow people down when driving, but more to encourage the appropriate use of gears and limiting excessive accelerations. All of which can be done with little or no effect to travel times. Eco-driving should also encourage the driver to plan ahead and anticipate traffic flow, this not only helps to avoid unnecessary stops (and the subsequent use of inefficient 1st and 2nd gears [JOH03]) 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 [EVA79] 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.

One possible expected outcome from the analysis conducted to answer this RQ was the decrease in average speed when using those NDs which are principally designed to give safety related feedback and speed limit advice. This was not born out in the analyses conducted thus far. Feedback presented to the driver in GER DFOT1 was information on speed limits of the current road, this was in the form of both information (i.e. what the current speed limit is) and alerts (warning the driver when they exceed this limit). With UKDOFT3 safety feedback was presented which encouraged drivers to maintain a safe distance headway to the car in front. Neither study exhibited a difference in average speed for the entire journey (GER DFOT1) or different road types (UKDFOT3). Reasons for this lack of difference may be the 'controlled' nature of DFOTs 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 analysis of LFOT data will hopefully highlight if any difference occur in naturalistic driving where the driver may feel less like they are 'under assessment' and more likely to drive at their natural speed (whether this is adhering to posted speed limits or not).

However, further 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 [ALM90]. This is considered to be a compensatory behaviour in an attempt to reduce workload, as well as increasing perceived safety margins [HAI00], and so could be indicative of increased distraction.

Conclusions for the EnvRQ1 'Is average speed affected' as determined from this analysis suggest that the NDs evaluated thus far (GDS, FCW and SI/SA) has not led to any changes in average speed being observed. For a green driving system this could be perceived as a positive outcome; however, changes in speeding behaviour or inappropriate speed, as opposed to average speed, may be a more defined indicator for the positive (or negative) effects of NDs.

5. E-RQ 2 Is speed homogeneity affected?

5.1. Data

The analyses of this hypothesis "E-RQ 2 Is speed homogeneity affected?" should be based on data coming from the different data loggers (objective data), although with additional information coming from the travel diaries.

Preliminary analyses have been based on DFOT data coming from a DFOT carried out by UK (namely, UKDFOT2). In this DFOT, Foot-LITE system was used, which consists of a combination of a Green Driving Support (GDS) system with Lane Departure Warning (LDW) and Forward Collision Warning (FCW).

FOT	Function / s	Data Type	Number of participants	Total driving km	Total driving hours/minutes
UK DFOT2	Green Driving	Logged	40	4800	50 hours

Table 3; Set of data analysed in E-RQ2

<u>Reasons for Exclusion of Data</u>

The smart driving system Foot-LITE collected data for the entire journey (or at least a large section of it) in both conditions for 28 subjects out of the 40 participants. However for the other twelve it did not log all data or sometimes it crashed during the test.

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.

Additional, it was detected that subject 6 had considerable less data compared to the other participants so that these data were excluded, too.

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

Green driving function is expected to have an effect contributing to homogenize speed.

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

Within UKDFOT2 data, only Green driving is analysed, so there is not any combination of functions and hence any effect seen in this data is due to the green driving support.

Data Selection, filtering and post processing for analysis

Data were selected from UK DFOT2 based upon the following criteria:

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

Statistical Testing

Non parametric test, specifically Mann Whitney test was used to test homogeneity between data in baseline condition and data with the Green Driving function activated.

H0: The distributions homogeneity can be considered the same;

against the alternative hypothesis

H1: The distributions homogeneities are different.

5.2. Speed homogeneity

This study has been based on just speed distributions (actual speeds that the vehicles were driven at discrete points in time during individual trips according to the data-loggers) but subsequent analyses will incorporate the speed limit information in relation to current speed (considered in terms of maximum speed and mean speed). In this sense, these proposed indicators (dependent variables) to analyse speed homogeneity will be used:

- Speed distribution
- Speed variance or standard deviation
- Difference between speed limit and maximum speed
- Difference between mean speed and maximum speed

Results

Data from UK DFOT 2 shows a significant change in the speed distribution between both conditions (baseline and Foot-Lite device use).

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.

Table 4; Results from Mann Whitney test

Caveats

This test is sensitive and given that there are large amounts of data available, results may be affected by this large amount of data (1.5Million). Overall, it may not be 'realistic' to analyses all of the data but for this preliminary analysis, assumptions have to be made in order to conduct the analysis.

Also, the differences found can be due to external agents other than the studied function, e.g. traffic flow, weather conditions, etc.

5.3. Discussion

According to E-RQ2 analyses, differences have been found between baseline condition and Foot-Lite device use. These differences indicate greater speed homogeneity in the Foot-Lite condition, which leads to reduced fuel consumption. Although part of this effect may be due to the use of the Green Driving function, it must be considered that other factors could be affecting as well.

As explained before, other indicators for the analysis of speed homogeneity will be used, such as speed variance (or standard deviation), difference between speed limit and maximum speed and finally, difference between mean speed and maximum speed.

It should be noted Speed distribution can be influenced by other external agents such as adverse climate conditions, road traffic, time, etc. However, UKDFOT2 was planned in order minimize these concerns. Therefore, the tests were carried out in similar traffic conditions; time of day, weather, etc. so that it could be ensured that there was no influence of seasonal effects on this particular study.

In relation to the statistical techniques, a group comparison will be used for these analyses, considering the use of the function (independent variable) together with the type of road, the type of journey and specific personal characteristics as covariates (depending on the availability and reliability of data sets).

Thus, the next steps will be dedicated to the analysis of data coming from other test sites, as soon as they become available.

6. E-RQ 3 Is speed distribution affected?

6.1. Data

Similarly to the previous RQ, the analyses of this hypothesis "E-RQ 3 Is speed distribution affected?" is based on data coming from the different data loggers with additional information from travel diaries.

Thus, the following data set was used for these preliminary analyses:

FOT	Function / s	Data Type	Number of participants	Total driving km	Total driving hours/minutes
UK DFOT2	Green Driving	Logged	40	4800	50 hours

Table 5. Set of data analysed in E-RQ3

In this DFOT, Foot-LITE system was used, which consists of a combination of a Green Driving Support (GDS) system with Lane Departure Warning (LDW) and Forward Collision Warning (FCW).

Reasons for Exclusion of Data

The smart driving system Foot-LITE collected data for the entire journey (or at least a large section of it) in both conditions for 28 subjects out of the 40 participants. However for the other twelve it did not log all data or sometimes it crashed during the test.

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.

And it was detected that subject 6 had considerable less data compared to the other participants so that these data were excluded, too.

Anticipated effect of function to be tested

It is anticipated that Green driving function will contribute to have a smother speed distribution.

Anticipated influence of combinations of functions

Within UKDFOT2 data, only Green driving 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.

Data Selection, filtering and post processing for analysis

Data were selected from UK DFOT based upon the following criteria:

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

Statistical Testing

Speed data were categorised into 8 categories to perform a Chi-square test between both distributions.

Firstly it was performed a chi-square test with the full set of data (1.5Million) and afterwards, the same test was used with a 200 data sample.

H0: Speed distribution is not affected;

against the alternative hypothesis

H1: Speed distribution is affected.

6.2. Speed distribution

For the analyses of this RQ, the actual speed distribution itself will be studied.

Results

For this hypothesis, Chi-square test shows that speed distribution had changed between baseline and Foot-Lite device. But this significance could be due to the large amount of data and thus, this is the reason why the same test was conducted with a reduced sample.

	Value	degress of freedom	Sig.
Chi-square	6434,99	7	,000
N	1522383		

Table 6. Chi-squared test with full set of data (1.5M data)

On the contrary, for the 200 data sample, the Chi-square test shows that there is not such a difference between both distributions.

	Value	degress of freedom	Sig.
Chi-square	2,408	7	,934
N	200		

Table 7b. Chi-squared test with a selected sample (200 data)

Caveats

This test is sensitive and given that there is a large amount of data available, results may be affected by this large amount of data (1.5 Million). For this reason and in order to check differences in distribution, two analyses have been performed, namely on the whole data set and on a reduced data sample. A summary of the data is shown in table 7b.

Descriptive Statistics

N	Minimum	Maximum	Mean	Std. Deviation
668643	,0	135,1	50,683	33,5010
853627	,0	146,1	47,991	34,2414
668272	0	135	50,63	33,005
852882	0	145	47,61	33,808

Table 7b; Descriptive statistics of the full data-set.

6.3. Discussion

According to E-RQ3 analyses, no differences have been found between baseline condition and Foot-Lite device use. Thus, it can be stated that subjects followed similar speed distributions in both conditions.

For the next stage of the analysis, the use of the function together with the type of road, the type of journey and particular personal characteristics (depending on the availability and reliability of data sets) will be considered.

Thus, the next steps will be dedicated to the analysis of data coming from other test sites, as soon as they become available.

7. E-RQ 4 Is the number of journeys affected?

7.1. Data

Environment research question EN-RQ4 “Is the number of journeys affected?” were answered for the preliminary results by analysing travel diary data and responses to questionnaires. Travel diary data was from LFOT2 in Sweden and LFOT in Valladolid/Spain. Sweden had collected travel diaries three times and Valladolid four time during one week. In Sweden the number of participants who had filled the travel diary per period varied between 52 and 86 and in Valladolid between 90 and 117.

In Swedish LFOT2 participants had green driving and navigation which included speed information and alert in their use. In the LFOT of Valladolid the participants had navigation as well as speed information and alert in their use. The results were analysed per travel diary data collection period i.e. for baseline and for treatment phase. Impacts in number of journeys cannot be assessed by use of single function but by availability of a bundle of functions.

The questionnaires included the question “Do you think any of the following will change / has changed with your access to function X?” and one alternative was “the number of journeys you make by car” The questionnaires were analysed from Swedish LFOT2 and LFOT4 as well as LFOTs of Finland, Valladolid/Spain and Italy. The number of responses varied between FOTs, functions and phase of study. The smallest number of respondents per questionnaire was 18 and the largest 119.

For environmental impacts only number of car journeys reported in travel diary was studied. The number of journeys made by other modes of transport was left out. Statistical comparison of mean in travel diary data was performed with ANOVA. For the responses of questionnaires, statistical comparison was made with Friedman’s test.

7.2. Number of journeys

The average number of car journeys per day reported in travel diary is presented for Sweden and Spain in Figure 5. ANOVA showed no statistically significant differences between periods.

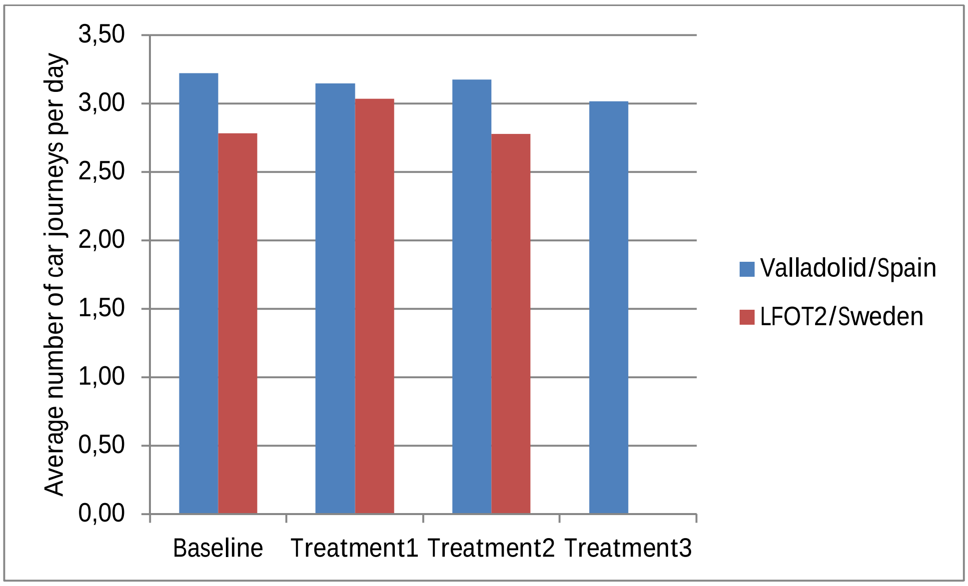

Figure 5. Average number of car journeys per day in different phases of FOT.

Participants were asked the impact of each function on number of journeys they make by car. A summary of responses is presented in Table 8. Results show clearly that most respondents did not expect nor experience changes in the number of car journeys. The proportion of choice "no change" was higher after the FOT (post-questionnaire) than the expectations before the start of the FOT (pre-questionnaire) although Friedman's test showed no statistically significant changes between questionnaires answered in different phases of the FOT. The majority of those participants who expected a change in number of journeys expected a small decrease in Finnish and Swedish LFOTs but a small increase in Italian and Spanish LFOTs.

Function	FOT	No change (% of responses), pre-questionnaire	No change (% of responses), post-questionnaire
Green driving	FI-LFOT	93	98
	SWE-LFOT2	81	95

Navigation	IT-LFOT	91	96
	SWE-LFOT2	90	93
	SP/V-LFOT	92	99
Speed info/alert	FI-LFOT	96	99
	IT-LFOT	91	93
	SP/V-LFOT	95	99
Traffic info	FI-LFOT	96	99
	SWE-LFOT2	89	98
	SWE-LFOT4	93	95

Table 8. Proportion of respondents who expected no change or had experienced no change in number of car journeys because of having the function

7.3. Discussion

Environment research question EN-RQ4 "Is the number of journeys affected?" were answered for the preliminary results by analysing travel diary data from LFOTs of Sweden (LFOT2) and Valladolid/Spain and questionnaires from LFOTs of Finland, Italy, Valladolid/Spain and Sweden (LFOT2 and LFOT4).

Results based on travel diary showed no difference in number of car journeys between baseline and treatment period during which green driving, navigation and speed information/alert were available in Sweden and navigation and speed information/alert in Spain. The result from questionnaires confirmed that most participants assessed that their number of car journeys had not changed due to having these functions.

Final analysis will include also logger data. The results obtained by analysing the travel diary data will be complemented by data from Finnish LFOT, UK LFOT and Italian LFOT and results of questionnaire data will be complemented by UK LFOT data.

8. E-RQ 5 Is the distance travelled affected?

8.1. Data

Environment research question EN-RQ5 “Is the distance travelled affected?” were answered for the preliminary results by analysing travel diary data from Swedish LFOT2 and LFOT in Valladolid/Spain. Sweden had collected travel diaries three times and Valladolid four time for one week. In Sweden the number of participants who had filled the travel diary per period varied between 52 and 86 and in Valladolid between 90 and 117.

In Swedish LFOT2 participants had green driving and navigation which included speed information and alert in their use. In the LFOT of Valladolid the participants had navigation as well as speed information and alert in their use. The results were analysed per function.

In travel diary data only commuting journeys made by car were included as distance travelled was studied for comparable origins and destinations. Average distance of commuting journeys made by car was calculated separately for journeys when certain function was in use and for journeys when no function was used. Those drivers were selected for the analysis who had reported commuting journeys both with a certain function and without any of the functions.

Statistical comparison of mean was performed with paired-sample T-test. Distance travelled of journeys with a certain function was compared pairwise to those made without using any of the functions during the same travel diary data collection period to get the result per function.

8.2. Distance travelled

Average distance of commuting journeys was calculated for each participant for each travel diary data collection period separately for commuting journeys when a certain function was in use and when no functions were in use. There no statistically significant differences (cp. Table 9) in distance for any of the function in Sweden. However, in Valladolid, Spain the distance was statistically significantly ($p = 0.100$) longer for those journeys when speed information/alert was in use compared to those commuting journeys when no function was in use. However, the difference was small: 0.47 km. For navigation, there was no statistically significant difference in Spain either. Individual observations were plotted in Figure 6 - Figure 9. Figures confirm the statistical result as most observations are very close to curve y = x.

Function	LFOT	Distance, with function	Distance, no function	N	p
Speed info/alert	Spain/Valladolid	18.10	17.63	43	0.100*
	Sweden	23.48	21.75	12	0.306
Navigation	Spain/Valladolid	18.71	18.59	15	0.160
	Sweden	25.34	21.05	10	0.317
Green driving	Sweden	20.35	20.57	11	0.970
Traffic info	Sweden	17.68	21.59	13	0.293

Table 9. Average distance (km) of commuting journeys made by car. Distance of journeys with a certain function was compared pairwise with paired-sample T-test to those made without using any of the functions during the same travel diary data collection period

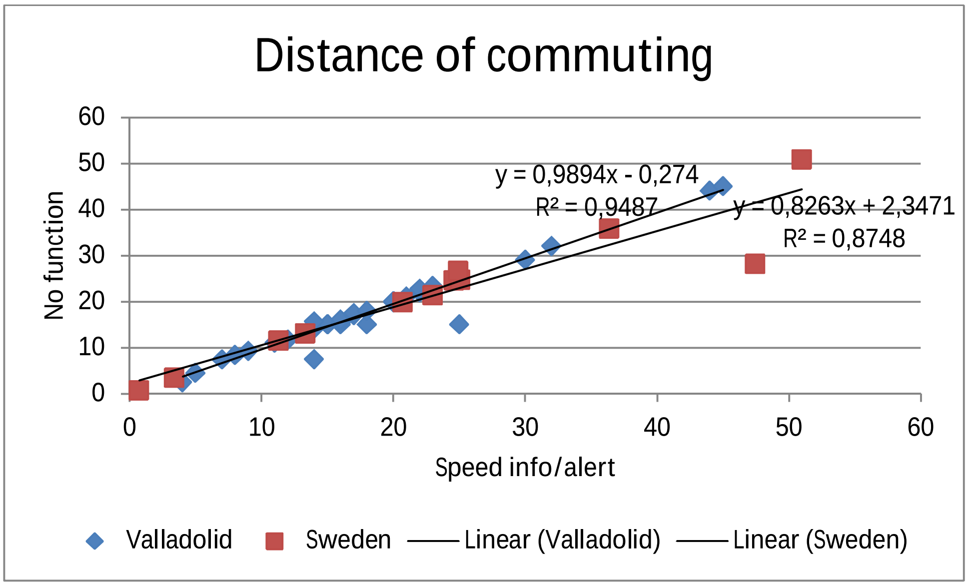

Figure 6. Average distance of commuting journeys made during one travel diary data collection period per person for commuting journeys when speed information/alert was in use and when no function was in use

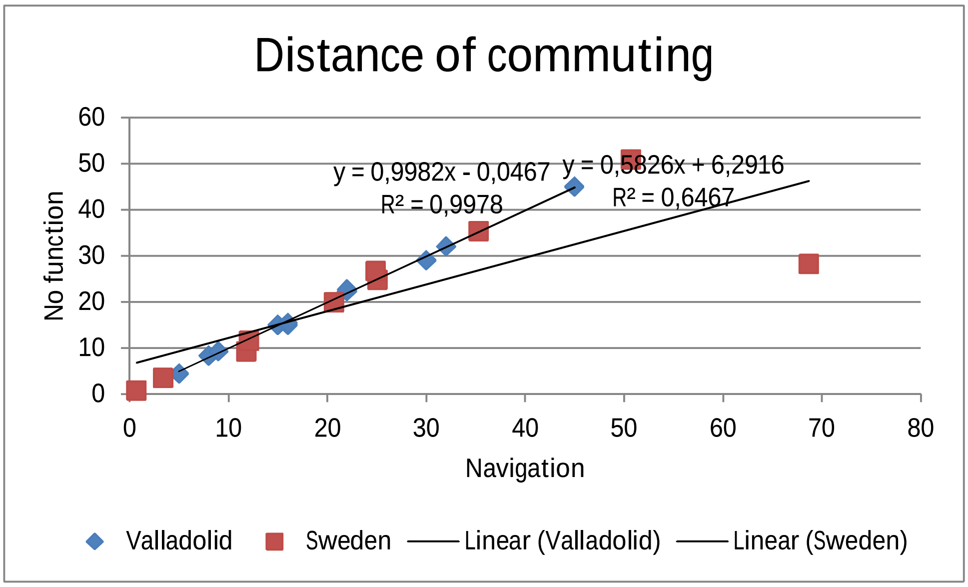

Figure 7. Average distance of commuting journeys made during one travel diary data collection period per person for commuting journeys when speed navigation was in use and when no function was in use

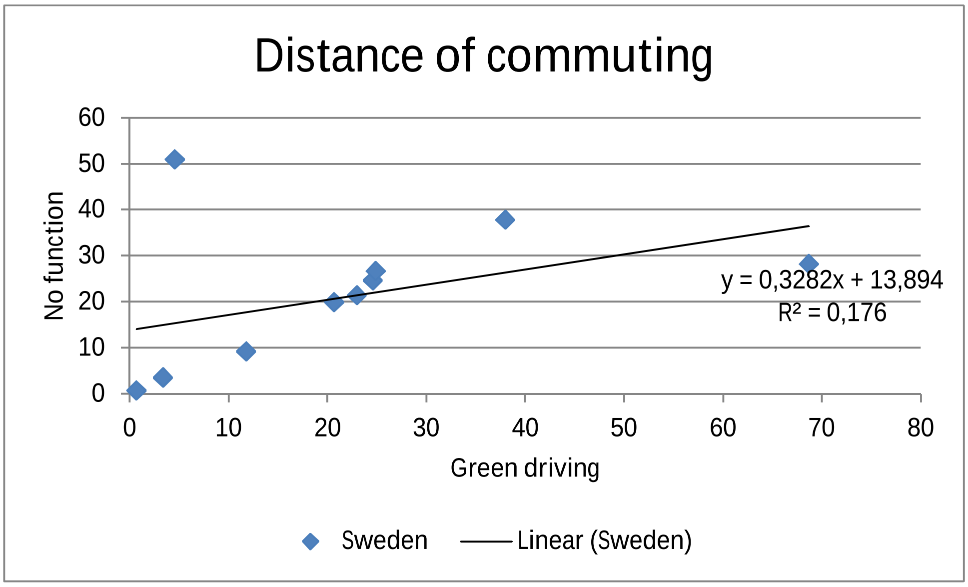

Figure 8. Average distance of commuting journeys made during one travel diary data collection period per person for commuting journeys when green driving application was in use and when no function was in use.

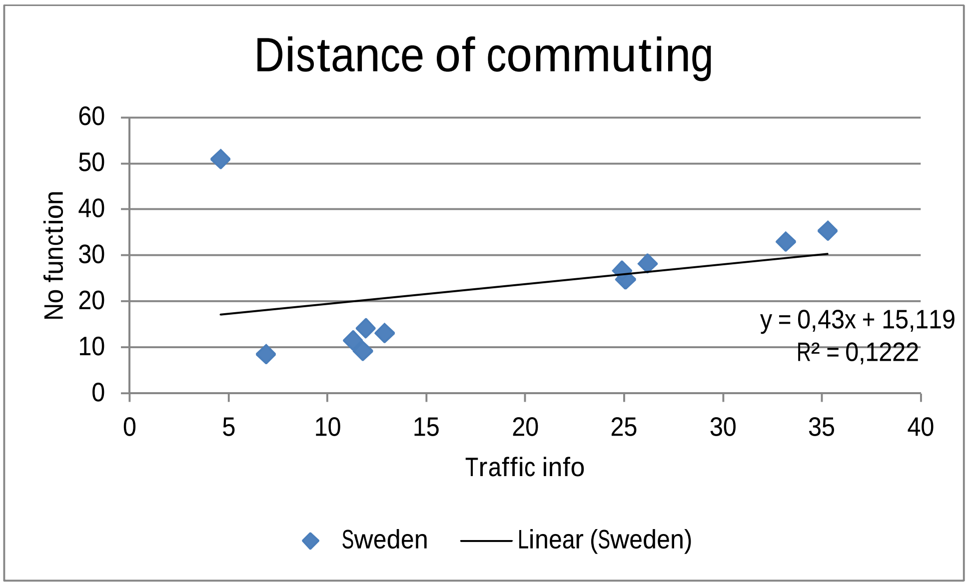

Figure 9. Average distance of commuting journeys made during one travel diary data collection period per person for commuting journeys when traffic information was in use and when no function was in use

8.3. Discussion

Environment research question EN-RQ5 "Is the distance travelled affected?" were answered for the preliminary results by analysing travel diary data from Swedish LFOT2 and LFOT in Valladolid/Spain.

The results showed no impact in distance travelled of journeys due to using green driving application, navigation or traffic information. In Spain a small but statistically significant difference in distance travelled for commuting journeys was seen for speed information and alert. In Sweden, there was no statistically significant difference for that function either.

The only uniquely identified origin destination pair in travel diary data is commuting journeys. For many people commuting journeys are made during peak hour and route has been optimised even before the trial. Consequently, no great impacts of device use were expected.

Final analysis will include also logger data. From logger data all origins and destinations used several times can be identified. Consequently, the potential impact in distance travelled of journeys can be studied for more origin destination pairs than just for those made between the home and the place of work. However, as (at least most) test sites did not log the use of function, the impact can be studied for the possibility to use a function rather than for the actual use of it. The results obtained by analysing the travel diary data will be complemented by data from LFOTs in Finland, UK and Italy.

People are not precise in filling in the travel diaries (incorrect distance or wrongly used OD indexes) and manual transformation to data may include mistakes. This is seen as outliers in the data. Therefore a systematic filtering procedure should be set up for the analysis of final results.

9. E-RQ 6 Is road type and choice of routes affected?

9.1. Data

This RQ consist of two hypotheses, the first one, "Is road type used affected" and the second "Is the choice of routes affected".

In terms of road type, this research question will be answered by finding common trips from the legs tables, and then using the map matching tables to find the type of road for these common trips. The base line data can then be compared to the treatment data. Depending on the expected outcome of a particular function, different analyses will be required. Some functions might have an impact on the "mean road type", Navigation might be an example, shifting traffic from highways to rural roads since you might dare taking shortcuts when you are guided. For other functions, such as traffic information, variance might be more interesting, showing if the participants use the information to take the best route due to the current traffic situation.

In terms of route choice, what could be answered is a slightly modified hypothesis: "There is a reported change in route choice.", if route choice is interpreted as limited to type of road.

- For each function, the following question is posed:"Do you think that any of the following has changed due to your access to the (function/device)....?" The Participants are asked to indicate decrease/ no change/ increase regarding first the use of motorways/ highways and second the use of rural roads.
- Comment: It is possible to check for trends given that the same question is posed in the User Uptake Questionnaire During-test.

9.2. Is road type and choice of routes affected?

The pilot analysis of modified hypothesis "Participants report a change in the choice of routes (road type) when the device is used compared to when it is not" was based on question 4 (Do you think that any of the following will change with your access to the system tested?), sub-questions x (Your use of highways/motorways?) and xi (Your use of rural roads?) of the post test UU questionnaire for one of the FOTs (The Swedish LFOT2)

Most of the participants assessed that having access to tested TeleFOT functions have not changed their use of highways/ motorways (85.3-92.2%) or rural roads (89.7-92.2%). Of the participants that reported that they had changed their choice of road type, most reported a slight decrease of their use of highways and a corresponding increase in their use of rural roads with Navigation support having the relatively greatest impact and Green driving support the lowest (cp. Figure 10 and Figure 11).

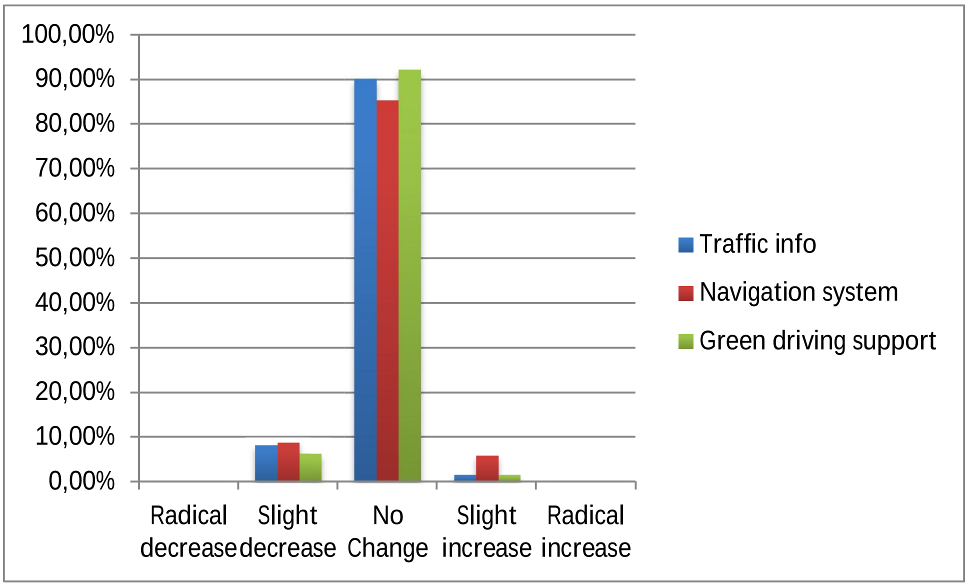

Figure 10. The reported effects of the tested functions on the participants' use of highways/motorways

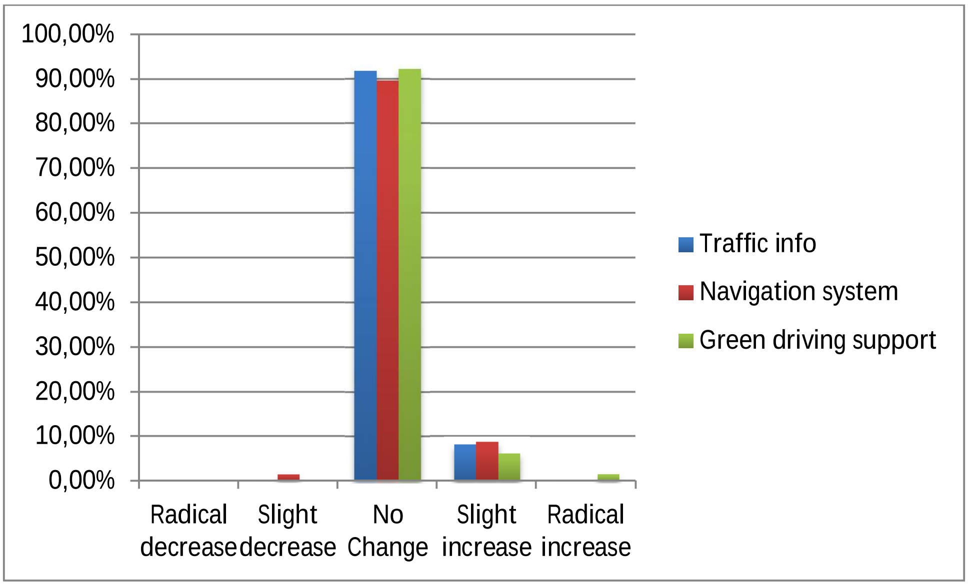

Figure 11. The reported effects of the tested functions on the participants' use of rural roads

In terms of choice of road type, the work with finding suitable statistical methods for the available logged data, is still on-going and will be developed further for the final Deliverable within the TeleFOT Environment (4.6.3). Looking at means from the Swedish LFOT2 data set, it is obvious that the tested functions (Navigation support, Traffic information, and Green driving support) have had very little effect (cp. Table 10). The differences between the baseline period and the treatment period are within a per cent.

	Mean, baseline (N=17248)	Mean, treatment (N=20371)
percent_roadtype_0	13.07	13.01
percent_roadtype_2	14.01	14.72
percent_roadtype_3	21.67	20.93
percent_roadtype_5	19.77	19.92
percent_roadtype_6	29.45	28.88

Table 10. Mean route choice, based on travelled distance per road type and trip

In terms of variance, the search for a suitable statistical method is still on, but plots on the relative differences between trips in terms of route choice show that there might be some effects on that level (cp. Figure 12)

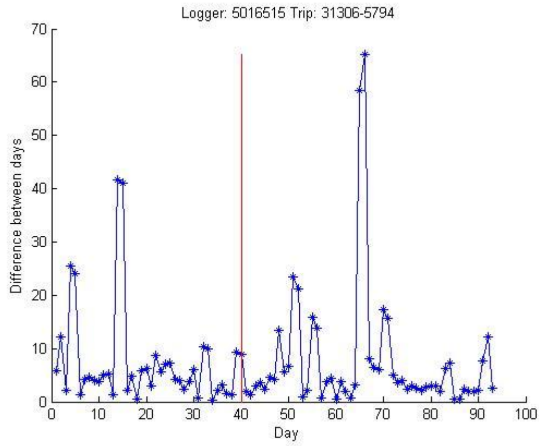

Figure 12. Plot of variance for one participant over a 95 day period

Since there might be seasonal effects on road choice, participants perhaps choosing larger roads when it is winter and snowy, plots were made showing weighted road type mean per day. No such effects could be spotted (cp. Figure 13).

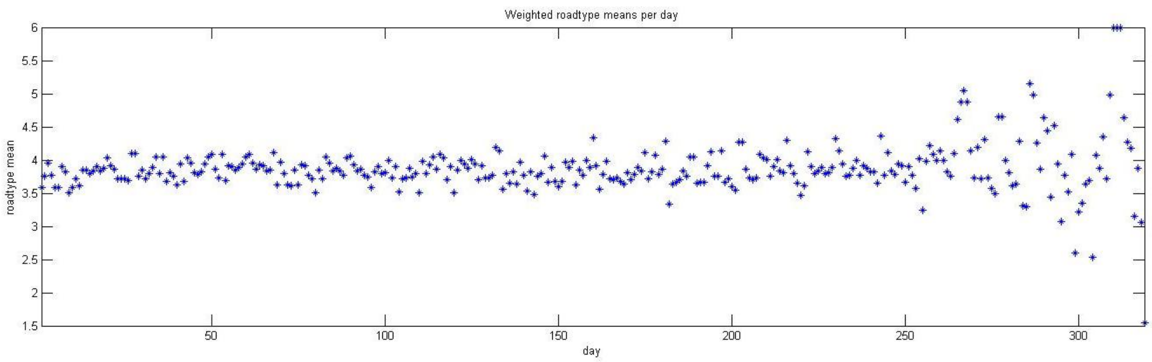

Figure 13. Weighted road type means per day

Figure 13: There do not seems to be any seasonal variations in road type choice. The reason for the plot getting scattered in the end is due to the relatively much lower number or trips by the end of the test.

9.3. Discussion

The preliminary results showed that the tested functions do not seem to have much effect on the choice of road type or on the reported choice of type of road. There is however the possible effect on variance to be investigated as well as the possibility that other devices, although with the same functions, will have a greater impact.

10. E-RQ 7 Is transport mode affected?

10.1. Data

The data available for the pilot analyses are travel diaries (collected during the Swedish LFOT2), and data collected by means of User Uptake Questionnaires (Before- During – After) during the Swedish LFOT2.

10.2. Is transport mode affected?

The hypothesis cannot be answered using the logged data since the loggers are mounted in the cars, and therefore only log trips using that mode of transport. Anyhow the hypothesis can be answered using data from travel diaries.

The participants are to indicate the travel mode for all trips during the defined period. As also type of journey is to be indicated, it is possible to carry out an analysis for commuter trips (code 1) and mode of transport (codes 1-18). The results indicate that the tested functions have no effect on the mode of transport (cp. Figure 14).

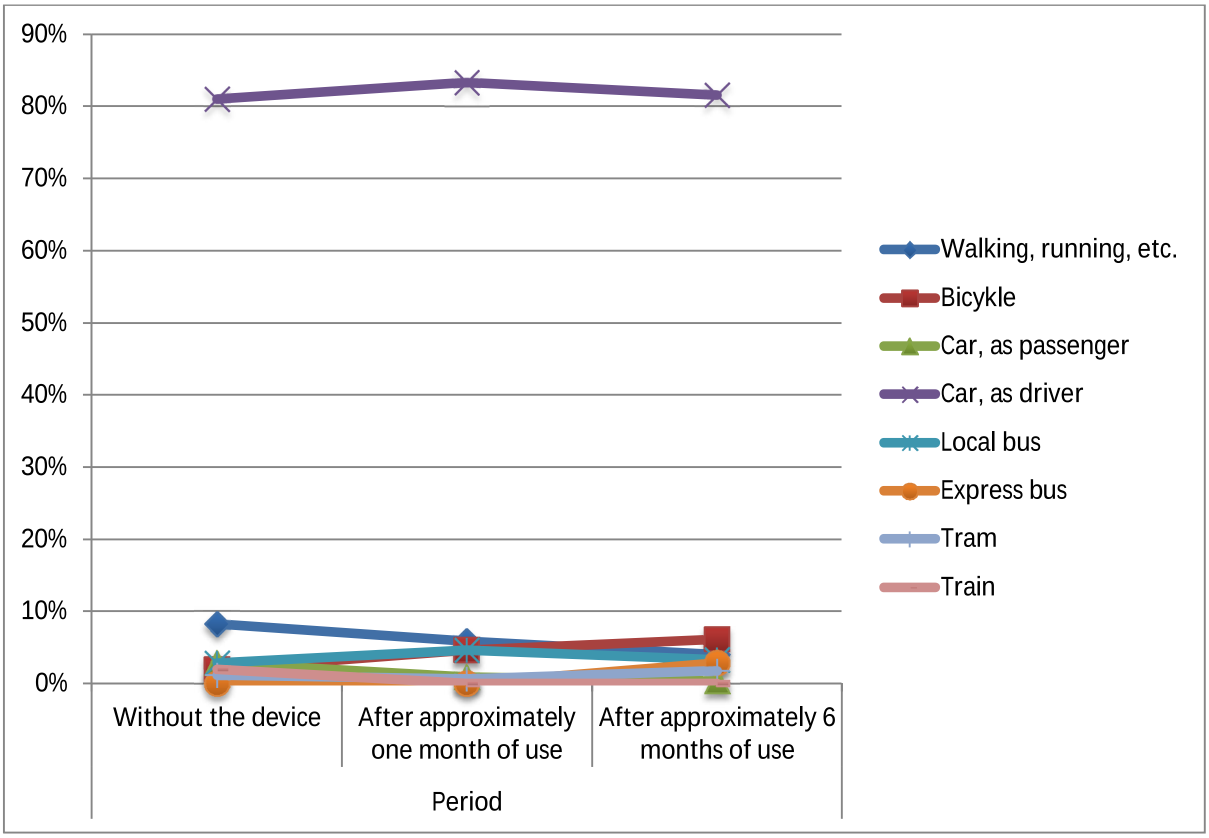

Figure 14. The uses of different modes of transport

One can see how some of the participant, come spring, change from walking to using their bike for commuting, and that the car is the dominating mode of transport.

The hypothesis cannot be answered using data from User Uptake Questionnaires. What could be answered is a slightly modified hypothesis: “There is a reported change in the use of private car for travelling.”

For the pilot test, the question above was only asked in the user uptake post test questionnaires. In order to check for trends during the test runs, the same question has been added to the User Uptake Questionnaire During-test questionnaires.

For each function, the following question is posed: ”Do you think that any of the following has changed due to your access to the (function/device)….?” The Participants are asked to indicate decrease/ no change/ increase re (i) the number of journeys made by car and (ii) the number of journeys made by public transport.

Most of the participants reported that the access to the tested functions had no effect on the number of car journeys made, nor on the number of journeys made with public transport (cp. Figure 15). Although small, there is a reported decrease in the number or car journeys and a corresponding increase in the number of journeys made with public transport.

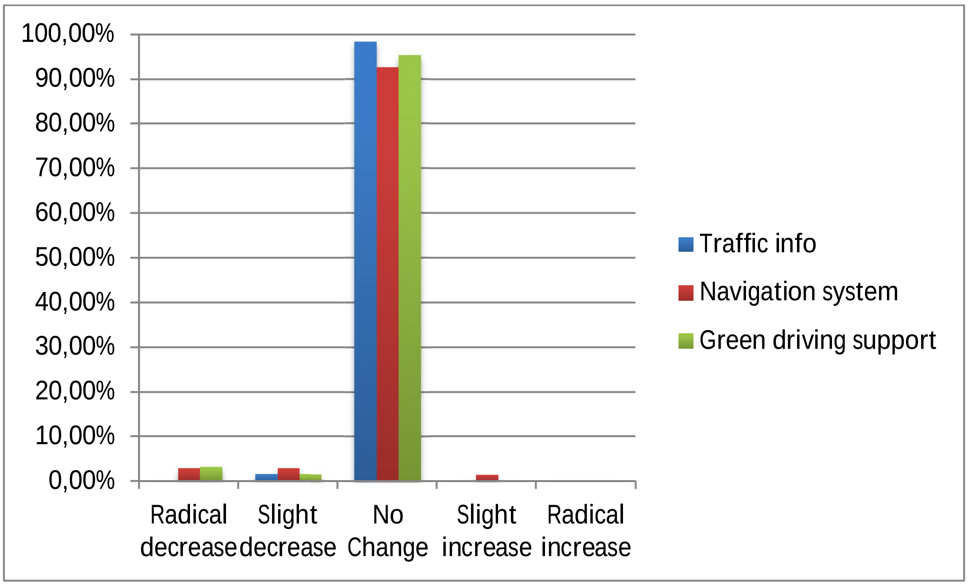

Figure 15. The reported effect on the number of car journeys made

10.3. Discussion

The preliminary results showed that the result was that none of the tested functions seemed to have any effect on the mode of transport. There is however some participants that perceive that they have decreased their car use and increased their use of public transport.

11. E-RQ 8 Is total fuel consumption affected?

11.1. Data

For the assessment of research question 8 “Is total fuel consumption affected?” the total amount of fuel, which is used inside a given period of time, is considered. This data can be obtained directly during the test runs via OBD and or CAN-interfaces, where the data of the flow rate meter can be gathered and added up to the total amount of fuel for each leg. Due to the fact that this data is only available in some of the FOTs (mostly DFOTs) the evaluation of RQ8 will be based primarily upon an indirect determination of the total fuel consumption by traffic flow simulation.

The fuel consumption can be calculated in simulation with detailed vehicle models. The current fuel consumption in every time step is known. By adding up each single value, the total fuel consumption of the simulation can be determined. The result of the traffic flow simulation is given in form of a relative change of total fuel consumption.

The first step for setting up the traffic flow simulation is to analyse data coming from FOTs in the project. The objective is to observe a change in driving behaviour due to the influence of the functions of the nomadic device. In the traffic flow simulation the influence of the system will be assessed by adaptations to the implemented driver model. Adaptable driver parameters of the driver model are e. g. safety need, desired velocity, compliance with restrictions on overtaking or compliance with speed limits

The first FOT, which has been partly analysed, is the German DFOT. In the German DFOT 12 subjects drive four pre-defined routes with three configurations (12 trips = ~1260 km / driver). The configurations are:

- Functions of nomadic device (static navigation, speed limit information, speed alert) [A]
- Advanced driver assistance systems (adaptive cruise control, forward collision warning, lane keeping assist) [B]
- Combination of A and B [C]

11.2. Is total fuel consumption affected?

In the evaluation a total amount of fuel used to cover each trip is calculated. This value is given in litres [l].

8 of 12 subjects of the German DFOT have been analysed regarding the above mentioned adaptable parameters for the different configurations. Table 11 shows the percentage of data which contributes to evaluate the speeding ratio at different speed limits and at all further boundary conditions (no preceding vehicle, speed limit available, right road type, speeding of the driver). The speeding ratio describes how the driver complies with the speed limits.

subject	speeding ratio 70 km/h			speeding ratio 80 km/h			speeding ratio 100 km/h		
	A	B	C	A	B	C	A	B	C
1	1.99	2.58	3.49	1.21	1.06	0.93	1.33	0.69	0.75
2	1.84	5.47	2.20	0.54	0.83	0.65	0.40	1.92	1.29
3	1.53	0.90	0.57	0.11	0.38	0.48	1.01	0.67	1.09
4	2.10	0.88	1.08	0.75	0.53	0.62	1.38	0.35	1.84
5	1.85	1.62	0.57	0.43	0.45	0.75	0.67	1.73	1.28
6	3.87	0.97	2.20	0.61	0.41	0.21	2.10	1.17	0.80
7	0.88	1.38	2.25	1.46	0.26	0.30	1.64	1.46	0.64
8	1.22	1.64	2.11	0.57	0.54	0.62	1.42	1.00	1.11

Table 11. Contribution of data to speeding ratio [%]

Since the amount of useful data (no preceding vehicle, speed limit available, right road type, speeding of the driver) is very small (6% or less per test person), there cannot be a statistical reliable change of driving behaviour observed during the German DFOT.

11.3. Discussion

The first DFOT has been partly analysed regarding change of driving behaviour due to the functionality of the nomadic device. The analysis of the first set of available data could not show a significant change in driving behaviour, so no adaptable parameters could be found. Therefore the application of traffic flow simulation will show no effects with regards to fuel consumption.

The next steps are to analyse data from other FOTs, which can support the traffic flow simulation. A change of driver behaviour is necessary as an input to the simulation strategy.

The research question "Is speed affected?" with its hypothesis "H4.1 The number of speed violations / proportion of time spent in excess of the speed limit changes with the device" from the safety impact area has also a big potential to contribute a possible influence of the nomadic device on the driving behaviour. Analysis results of this research question will be taken into account for the final results.

Only, if a real change in driving behaviour can be figured out from the FOTs, traffic simulation will show a change on total fuel consumption.

12. E-RQ 9 Is average fuel consumption affected?

12.1. Data

In the assessment of research question 9 “Is average fuel consumption affected?” the total amount of fuel used over a given driven distance is considered. This data can be obtained directly during the test runs via OBD and or CAN-interfaces, where the data of the flow rate meter can be gathered and added up to the total amount of fuel and the driven distance can be calculated from speed or GPS data for each leg. Due to the fact that this data is only available in some of the FOTs (mostly DFOTs) the evaluation of RQ9 will be divided into a direct assessment and into an indirect determination of the average fuel consumption by traffic flow simulation.

The fuel consumption can be calculated in simulation with detailed vehicle models. The current fuel consumption in every time step is known. By adding up each single value, the total fuel consumption of the simulation can be determined. The result of the traffic flow simulation is given in form of a relative change of average fuel consumption.

The first step for setting up the traffic flow simulation is to analyse data coming from FOTs in the project. The objective is to observe a change in driving behaviour due to the influence of the functions of the nomadic device. In the traffic flow simulation the influence of the system will be assessed by adaptations to the implemented driver model. Adaptable driver parameters of the driver model are e. g. safety need, desired velocity, compliance with restrictions on overtaking or compliance with speed limits

One of the first FOTs, which has been partly analysed for the traffic flow simulation as well as for the direct assessment, is the German DFOT. In the German DFOT 12 subjects drive four pre-defined routes with three configurations (12 trips = ~1260 km / driver). The configurations are:

- Functions of nomadic device (static navigation, speed limit information, speed alert) [A]
- Advanced driver assistance systems (adaptive cruise control, forward collision warning, lane keeping assist) [B]
- Combination of A and B [C]

Another DFOT which has been analysed for the direct assessment method is the UK DFOT2. 35 drivers completed the DFOT in control condition without any system as well as with a green driving application (Foot-Lite). The length of the route in this DFOT is approx. 62 km, so that 2170 km have been analysed regarding average fuel consumption. In the direct assessment the fuel gauge signal is analysed.

12.2. Is average fuel consumption affected?

The data of 8 of 12 subjects of the German DFOT has been analysed regarding their average fuel consumption during their test runs.

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) (cp. Table 12). 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	maximum	mean	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 12. Min, max, mean and standard deviation of avg. fuel consumption of 8 subjects

In the UK DFOT2, it could be seen that there is a statistical significant change of average fuel consumption between the control and the treatment condition ($t(34) = 3.7$ with $p<.001$). Figure 16 shows the fuel savings of each test subject on a percentage basis.

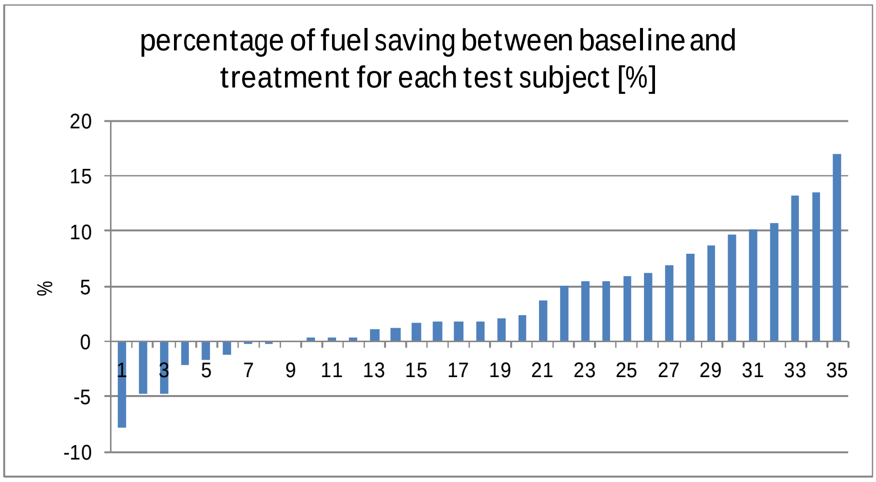

Figure 16: Percentage of fuel saving with FootLite support

The mean value of fuel saving is 4.1 %.

12.3. Discussion

Since the analysis of E-RQ 9 is divided into two assessment methods, first results can be presented in this deliverable. While the bundle of functions (NAV, SI/SA) in the German DFOT show no statistical relevant influence on the fuel consumption, the green driving support function “FootLite” in the UK DFOT does. This was analysed with a direct approach by means of fuel gauge information in both cases. The effort to answer this research question by means of traffic flow simulation is described hereafter.

The first DFOT (in Germany) has been partly analysed regarding the change of driving behaviour due to the functionality of the nomadic device. The analysis could not show a significant change in driving behaviour, so no adaptable parameters could be found

The next steps are to analyse other FOTs which can support the traffic flow simulation. A change of driver behaviour is necessary as an input to the simulation strategy.

The research question “Is speed affected?” with its hypothesis “H4.1 The number of speed violations / proportion of time spent in excess of the speed limit changes with the device” from the safety impact area has also a big potential to contribute to a possible influence of the nomadic device on the driving behaviour. Analysis results of this research question will be taken into account for the final results.

Only if a real change in driving behaviour can be figured out from the FOTs, a traffic simulation will show a change on average fuel consumption.

13. E-RQ 10 Is amount of CO emissions affected?

13.1. Data

In the assessment of research question 10 “Is amount of CO emissions affected?” the relative development of the CO emissions should be considered. This data can be obtained directly during the test runs via special measuring equipment inside the test vehicle. Due to the fact that this equipment is not available in the different FOTs the CO emissions cannot be determined directly.

An approach of calculating the CO emissions by an engine operating map, like it is done in the CO_2 approach, has been intended. Measurements of the CO emissions of a normal combustion engine showed that these emissions are depending very much on the status of the engine and the driver behaviour with regard to the engine controls (e.g. throttle actuation). These parameters are not considered inside the traffic flow simulation. The development of a CO emission model is not part of the TeleFOT project. Therefore a calculation of the CO emissions inside the traffic flow simulation tool PELOPS is not possible and has to be discarded from the environmental impact assessment.

13.2. Is amount of CO emissions affected?

Due to the fact that the CO emissions cannot be measured directly or be calculated by means of traffic flow simulation, an assessment of the effect on CO emissions by the system is not feasible.

13.3. Discussion

With the available data and the tools used inside the TeleFOT project an evaluation of the affect of the usage of the systems cannot be assessed.

14. E-RQ 11 Is amount of CO_2 emissions affected?

14.1. Data

In the assessment of research question 11 “Is amount of CO_2 emissions affected?” the relative development of the CO_2 emissions is considered. This data can be obtained directly during the test runs via special measuring equipment inside the test vehicle. Due to the fact that this equipment is not available in the different FOTs the CO_2 emissions will be determined indirectly by means of traffic flow simulation. The CO_2 emissions can be calculated with detailed vehicle models that allow calculating the operating points the engine is running in and with this information to derive the CO_2 emission from an engine operating map. This value can be added up to a total amount of CO_2 emissions. The result of the traffic flow simulation is given in form of a relative change of CO_2 emissions.

The first step for setting up the traffic flow simulation is to analyse data coming from FOTs in the project. The objective is to observe a change in driving behaviour due to the influence of the functions of the nomadic device. In the traffic flow simulation the influence of the system will be assessed by adaptations to the implemented driver model. Adaptable driver parameters of the driver model are e. g. safety need, desired velocity, compliance with restrictions on overtaking or compliance with speed limits

The first FOT, which has been partly analysed, is the German DFOT. In the German DFOT 12 subjects drive four pre-defined routes with three configurations (12 trips = ~1260 km / driver). The configurations are:

- Functions of nomadic device (static navigation, speed limit information, speed alert) [A]
- Advanced driver assistance systems (adaptive cruise control, forward collision warning, lane keeping assist) [B]
- Combination of A and B [C]

14.2. Is amount of CO_2 emissions affected?

In the evaluation a relative value of CO_2 emissions is calculated between configurations A, B and C.

8 of 12 subjects of the German DFOT have been analysed regarding the above mentioned adaptable parameters for the different configurations. Table 11 in chapter 11.2 shows the percentage of data which contributes to evaluate the speeding ratio at different speed limits and at all further boundary conditions (no preceding vehicle, speed limit available, right road type, speeding of the driver). The speeding ratio describes how the driver complies with the speed limits.

Since the amount of useful data (no preceding vehicle, speed limit available, right road type, speeding of the driver) is very small (6% or less per test person), there cannot be a statistical reliable change of driving behaviour observed during the German DFOT.

14.3. Discussion

The first DFOT has been partly analysed regarding change of driving behaviour due to the functionality of the nomadic device. The analysis of the first set of available data could not show a significant change in driving behaviour, so no adaptable parameters could be found. Therefore the application of traffic flow simulation will show no effects with regards to CO_2 emissions.

The next steps are to analyse data from other FOTs, which can support the traffic flow simulation. A change of driver behaviour is necessary as an input to the simulation strategy.

The research question "Is speed affected?" with its hypothesis "H4.1 The number of speed violations / proportion of time spent in excess of the speed limit changes with the device" from the safety impact area has also a big potential to contribute to a possible influence of the nomadic device on the driving behaviour. Analysis results of this research question will be taken into account for the final results.

Only, if a real change in driving behaviour can be figured out from the FOTs, a traffic simulation will show a change on CO_2 emissions.

15. E-RQ 12 Is the use of the systems influencing other traffic participants?

15.1. Data

In the assessment of research question 12 “Is the use of the system influencing other traffic participants?” the effect the use of the system on the surrounding traffic is assessed. The needed data cannot be gathered directly in the traffic environment itself, for the surrounding traffic is not part of the test setup and therefore not equipped with data loggers. Because of this the data is determined by traffic flow simulation.

The first step for setting up the traffic flow simulation is to analyse data coming from FOTs in the project. The objective is to observe a change in driving behaviour due to the influence of the functions of the nomadic device. In the traffic flow simulation the influence of the system will be assessed by adaptations to the implemented driver model. Adaptable driver parameters of the driver model are e. g. safety need, desired velocity, compliance with restrictions on overtaking or compliance with speed limits

The surrounding traffic will remain unchanged in the initial configuration. During the run of the simulation the vehicles will be interacting with each other, so that the changed behaviour of the “test driver” will also influence the other drivers inside the simulation.

Thus not only the effect on a single vehicle can be assessed but also the effect on the whole traffic based upon penetration rate of the system can be determined.

The first FOT, which has been partly analysed, is the German DFOT. In the German DFOT 12 subjects drive four pre-defined routes with three configurations (12 trips = ~1260 km / driver). The configurations are:

- Functions of nomadic device (static navigation, speed limit information, speed alert) [A]
- Advanced driver assistance systems (adaptive cruise control, forward collision warning, lane keeping assist) [B]
- Combination of A and B [C]

15.2. Is the use of the systems influencing other traffic participants?

In the evaluation different parameters, like acceleration and braking behaviour or the fuel consumption of surrounding vehicles is calculated and compared between the control/ before-use group and the test/ within-use group.

8 of 12 subjects of the German DFOT have been analysed regarding the above mentioned adaptable parameters for the different configurations. Table 11 shows the percentage of data which contributes to evaluate the speeding ratio at different speed limits and at all further boundary conditions (no preceding vehicle, speed limit available, right road type, speeding of the driver). The speeding ratio describes how the driver complies with the speed limits.

Since the amount of useful data (no preceding vehicle, speed limit available, right road type, speeding of the driver) is very small (6% or less per test person), there cannot be a statistical reliable change of driving behaviour observed during the German DFOT.

15.3. Discussion

The first DFOT has been partly analysed regarding change of driving behaviour due to the functionality of the nomadic device. The analysis of the first set of available data could not show a significant change in driving behaviour, so no adaptable parameters could be found. Therefore the application of traffic flow simulation will show no effects on the test vehicle and hence no effect on the behaviour of other traffic participants.

The next steps are to analyse data from other FOTs, which can support the traffic flow simulation. A change of driver behaviour is necessary as an input to the simulation strategy.

The research question “Is speed affected?” with its hypothesis “H4.1 The number of speed violations / proportion of time spent in excess of the speed limit changes with the device” from the safety impact area has also a big potential to a possible influence of the nomadic device on the driving behaviour. Analysis results of this research question will be taken into account for the final results.

Only, if a real change in driving behaviour can be figured out from the FOTs, a traffic simulation will show a change on the test vehicle and hence an effect on the behaviour of other traffic participants.

16. E-RQ 13 Is the use of the system influencing traffic surroundings?

16.1. Data

In research question 13 “Is the use of the system influencing traffic surroundings?” the effect the use of the system on the environment surrounding the traffic should be assessed. Therefore data about emissions influencing other traffic participants, like pedestrians or bicyclists, or other people, e.g. residents, would be needed. Among this data other parameters about emissions influencing the environment, e.g. noise, would be needed. This data is not gathered in any FOT and it cannot be determined by means of traffic flow simulation.

Therefore these effects cannot be evaluated during the environmental impact assessment in WP 4.6.

16.2. Is the use of the system influencing traffic surroundings?

Research question 13 cannot be answered with the available direct or indirect data in the TeleFOT project.

16.3. Discussion

In TeleFOT no data with regard to the assessment of the influence on the surrounding environment are collected. Due to the fact that these emissions, apart from CO_2-emissions, are not part of the traffic flow simulation this research question cannot be addressed during the evaluation process in WP 4.6.

17. CONCLUSIONS

In this deliverable the concept of the environmental impact assessment has been described in the first chapter, according to corresponding approaches, described in the given literature.

Afterwards for each research question significant data have been chosen with which the research question can be answered. Logged data from DFOTs as well as travel diaries and questionnaire data from LFOTs has been selected to answer the research questions.

For all research questions which can be answered directly by means of logged data, travel diaries or questionnaires, it could be shown that the necessary data is available and the analysis is going on. Statistical tests have been applied to approve the assumption.

The indirect approach by means of traffic flow simulation needs several steps to come to efficient results. After analysing real world data from the FOTs regarding driver behaviour, the driver model in the simulation has to be adapted. After the simulation the data has to be post-processed and the results can be assessed. Only, if a real change in driving behaviour can be figured out from the FOTs, a traffic simulation will show also a change.

With regard to the data base structure and the results of the preliminary tests some additional performance indicators, beneficial for the upcoming evaluation, could be identified and have been added to the TeleFOT data base in the aftermath to the pilot tests.

The additional performance indicators have been derived based upon the preliminary results of the environmental impact assessment but may also be used during the evaluation of other impact areas, like safety or mobility, too.

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