A subjective field operational test on LDW impact - Lessons learned and preliminary results

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A SUBJECTIVE FIELD OPERATIONAL TEST ON LDW IMPACT - LESSONS LEARNED AND PRELIMINARY RESULTS

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ABSTRACT

This paper presents the Italian Field Operation Test that is being carried out within the European project EuroFOT. Co-funded by the EC in the Seventh Framework Programme for Research and Technological Development (FP7), EuroFOT project aims at assessing a wide variety of Advanced Driver Assistance Systems (ADAS) across Europe. The Italian FOT is aimed at investigating the Lane Departure Warning system (LDW) deploying a large scale test that involves a sample of about 500 drivers and using a wide and differentiated set of self-reported questionnaires. The purpose of the Italian FOT is to investigate the subjective aspects about LDW system users' acceptance and the perceived impact of the LDW system on safety, driving behaviour and transport-related aspects. Given the huge sample, results are expected to accurately depict the actual impact of this function based on subjective data.

This paper presents details of the FOT methodology being carried out in the Italian test site, lessons learned about operational procedures and it introduces the preliminary results about FOT status regarding the recruitment process, questionnaire administration and response rates.

TESTING THE LANE DEPARTURE WARNING

Intelligent Transport Systems (ITS), including both safety and telematics applications, have been the subject of significant research and development in Europe in recent years and several models of passenger cars are now equipped with these systems as optional features (e.g. ACC, FCW, LDW, BLIS, etc.). However, implementing new technologies implies risks to manufacturers. Factors such as impact of these systems on overall traffic safety, markets' and users' acceptance are difficult to assess alone from internal testing.

The research project EuroFOT (http://www.eurofot-ip.eu) started with the main aim to demonstrate the effectiveness of, evaluate the impact of and encourage the deployment of intelligent vehicle systems on European roads. The EuroFOT project will mainly address the following research issues: (i) performance and capability of the systems; (ii) driver's interaction with and reaction to the systems; (iii) impacts of ITSs on safety, efficiency and environment. In order to reach its objectives, the project is applying the methodology that was developed in 2008 in the European project FESTA (http://www.its.leeds.ac.uk/festa/index.php) (2).

Different test centres are set up across France, Germany, Sweden and Italy focusing on 8 distinct functions for driver assistance in longitudinal and lateral control of the vehicle and on other advanced driving applications as Safe HMI and Fuel Efficiency Advisor (1). The EuroFOT Italian test site is investigating the Lane Departure Warning function for lateral control of the vehicle that is available on the Lancia Delta (Figure 1). This ADAS provides a feedback to the driver through a torque applied on the steering wheel as soon as the driver unintentionally is going close to or overcome a lane border, when the proper indicator light is not activated.

The purpose of the Italian test site of EuroFOT project is to investigate the subjective aspects of LDW system using a wide and differentiated set of self-reported questionnaires. Project participants keep driving their own car normally and no data acquisition systems are installed on board of vehicles.

Figure 1. Lancia Delta and the LDW system

RESEARCH HYPOTHESES

The methodology to assess LDW impact has been defined in strict accordance with the FESTA project research hypotheses referred to Advanced Driver Assistance Systems (Figure 2).
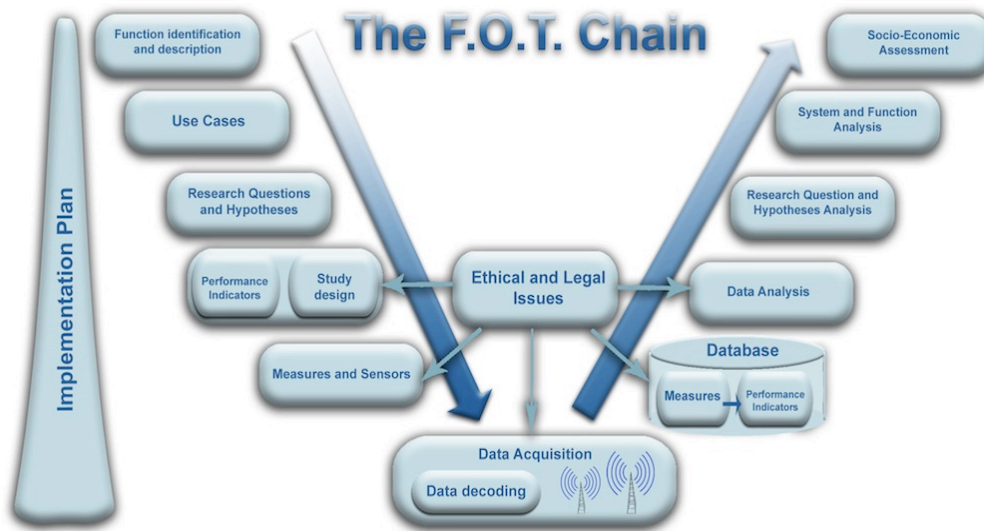
Figure 2. The FOT chain defined in FESTA project (2)

According to LDW system specifications and to the peculiarity of the subjective Field Operational Test, specific hypotheses have been defined in the Italian test site in order to be tested. Some of the research questions based on hypotheses are briefly listed hereafter: does the LDW decrease and mitigate incidents, near-crashes and accidents? Does the LDW influence lateral driving performance? Does the LDW increase the use of turn indicators in lane change situations? Does LDW increase usage more and more over time? Does LDW increase night driving? Does LDW warning lead to an appropriate driver reaction? Is LDW well accepted by the driver? Does LDW acceptance/adoption increase with LDW usage?

Performance indicators, i.e. the quantifiable way to detect how these hypotheses can be assessed, have been defined (2). The main subjective performance indicators about system are perceived safety, system acceptability, trust, perceived effectiveness, perceived usefulness, perceived satisfaction, perceived ease of use, affordability and mental workload.

Participants' responses to questionnaires will be treated using Item Response Theory (IRT) models that permit to generate measures from subjective responses (3). Repeated rounds of questionnaires will highlight changes in users' perceptions over time and, according to the design of experiment defined, they will allow analysts to test the hypotheses. Finally data collected will be analysed using multivariate analysis of variance methods (MANOVA), conducting T-tests in order to compare scores and identifying statistical algorithms.

DESIGN OF EXPERIMENT AND QUESTIONNAIRES

According to the design of experiment (DoE), this FOT has the objective to recruit about 250 drivers with a Lancia Delta equipped with the LDW system and about 250 drivers using the same type of car without the LDW as control group. Drivers have been followed in the first period of LDW use, i.e. 9 months (1). During such period, they provide their feedback about LDW system and their driving behaviour answering specific questionnaires or filling in forms related to specific events that happened during the vehicle usage involving the system.

The use of only subjective data provides a different level of reliability than objective data gathered from data loggers installed on board of vehicles. Nonetheless, given the aims of this project, the use of self-reported questionnaires is recommended because it permits to collect data about phenomena which are not directly observable, such as LDW user acceptance, driver reactions, subjective mental workload, users' trust in the system and so on.

The Design of Experiment (DoE) has been defined in order to improve as much as possible the subsequent data analysis and to detect if there are significant correlations between variables (Figure 2). Therefore questionnaires are designed to be filled-in by two different groups of users, called LDW Group and Control Group respectively. The first one (i.e. LDW Group) involves users driving their own car (i.e. Lancia Delta) equipped with the LDW system. In a first period of driving they should not use the LDW system ensuring a baseline period. In subsequent treatment period the same group of drivers will be able to use the LDW system and drive normally. This DoE will allow a within subject analysis in the LDW Group of users in order to detect differences in driving attitudes and behaviour, use of the system and the user acceptance of it over the test period. The Control Group involves users driving their own car (i.e. Lancia Delta) not equipped with the LDW system. Questionnaires will be also filled-in by these users but the items related to LDW system use will be not administered to them. The Control Group questionnaires are focused in driving attitudes and behaviours and in LDW system expectations. The Control Group and this DoE will allow a between subject analysis with the LDW Group users.

Total: 500 drivers									
		Drivers should not use the system in this period							
LDW Group (250 drivers)		Baseline LDW OFF		Treatment LDW ON					
Control Group (250 drivers)		NO LDW							
FOT month	month 0	month 1		end of month 3		end of month 5		end of month 7	end of month 9
Timing	First Contact	FOT start Q0		Q1		Q2		Q3	Q4

Figure 3. Italian FOT Design of Experiment

Five specific questionnaires are been designed for LDW Group and Control Group noticeably and they are being administered to drivers at deadlines defined every 2 months. All questionnaires are paper-based, but on line questionnaires has been set up as an option. Users

will be allowed to fill in web-based questionnaires developed through Limesurvey software (http://www.limesurvey.org).

These questionnaires will detect users' perception about safety, acceptance, trust, subjective mental workload, ease of use, effectiveness, usefulness and perceived value of the LDW.

In details the first questionnaire is an introductory survey in which the major social and demographic characteristics of drivers, including their driving habits, attitudes and behaviours will be collected. Some standardized tools are used to register these drivers' characteristics. The DBQ (i.e. Driving Behaviour Questionnaire) will be used to register the frequency of driving errors, violations and lapses judged by the drivers themselves. In DBQ questionnaire the drivers have to base their judgments on what they remember of their own driving over the past year (4).

A Specific sections of the first introduction questionnaire registers the risk perception of the drivers (i.e. Sensation Seeking questionnaire) and their attitudes toward driving behaviour. In the first questionnaires drivers of LDW Group are also asked to express their expectations about LDW system.

Other periodical questionnaires are filled-in by drivers every 2 months. These questionnaires will detect users' perception about safety, trust, ease of use, effectiveness, usefulness and value of the LDW, in strict accordance with the research hypotheses referred to the function and the corresponding performance indicators (i.e. the quantifiable way to detect how these hypotheses can be assessed) (2).

Periodical questionnaires aim to detect the viewpoint of the users about aspects of the LDW function as the perceived usability, the compatibility with the driving task, the perceived system consequences, the ease of use, the learnability and the perceived efficiency. In these periodical questionnaires, users could also be asked to evaluate themselves about their driving performance (6). A specific section in the periodical questionnaires is dedicated to the drivers' acceptance of the LDW system. Deriving from the Van Der Laan scale (8), the developed questionnaire register all indicators involved in system acceptance.

In addiction to the five questionnaires describe above, a weekly register has been provided to drivers of the LDW Group in order to detect and manage data about car and system usage during the FOT execution. All data collected are self-reported by drivers. A board diary is finally planned to detect driver's particular perception about LDW in specific scenario or events.

Section	Contact letter Screening questionnaire	Baseline - LDW OFF		Treatment - LDW ON			Weekly Diary	Event Register
		A	B	C	D	E		
Personal Details	x							
Vehicle use in brief	x							
Demographics		x						
Driving experience		x						
Impairment		x						
Last accidents		x						
Vehicle use and accidents in the last test period			x	x	x	x		
Attitudes towards driving behaviour		x				x		
Experience with technology		x						
Experience with ADAS		x						
Sensation seeking questionnaire		x						
Driving Behaviour Questionnaire DBQ		x			x			
Driving Style Questionnaire DSQ			x			x		
LDW Buying motivation		x						
LDW NOT Buying motivation								
Expectations about LDW - Extended Van Der Laan		x						
Subjective mental workload RSME		x	x	x	x	x		
Driving Quality Scale DQS		x	x	x	x	x		
Test Questionnaire about driving (in lane positioning)		x				x		
Test Questionnaire about LDW:								
- ease of use				x	x	x		
- ease of use (learning and familiarity)						x		
- trust				x	x	x		
- user practice				x	x	x		
- travel Patterns				x	x	x		
- system effects				x	x	x		
- usefulness				x	x	x		
- misuse				x	x	x		
- effectiveness				x	x	x		
- satisfaction				x	x	x		
LDW system description								
Acceptance of LDW - Extended Van Der Laan				x	x	x		
Willingness to pay - Affordability			x			x		
Social acceptability						x		
Advices to designers						x		
Debriefing - Overall system evaluation						x		
Debriefing - Study evaluation						x		
Km covered and percentage by other drivers							x	
Self-reported data from trip computer (Km, average speed, fuel consumption)							x	
Perceived frequency of LDW switching ON and activation							x	
Risk situations							x	
LDW impact and accidents in the last week							x	
Date and description								x
LDW system status (ON-OFF, Active-Not Active)								x
LDW warning and/or reaction								x
Situational variables at event:								x
- type of road								x
- road section								x
- manoeuvre								x
- weather (plus windy condition)								x
- part of the day (plus artificial lighting condition)								x
- traffic conditions								x
- self reported speed								x
- self reported level of distraction								x
- self reported level of attention								x
- trip duration								x
- self reported secodary task activity								x

Figure 4. Italian FOT questionnaire arrangement for LDW Group

Section	Contact letter Screening questionnaire	NO LDW				
		A	B	C	D	E
Personal Details	x					
Vehicle use in brief	x					
Demographics		x				
Driving experience		x				
Impairment		x				
Last accidents		x				
Vehicle use and accidents in the last test period			x	x	x	x
Attitudes towards driving behaviour		x			x	
Experience with technology		x				
Experience with ADAS		x				
Sensation seeking questionnaire		x				
Driving Behaviour Questionnaire DBQ		x			x	
Driving Style Questionnaire DSQ			x			x
LDW Buying motivation						
LDW NOT Buying motivation		x				
Expectations about LDW - Extended Van Der Laan						x
Subjective mental workload RSME		x	x	x	x	x
Driving Quality Scale DQS			x	x	x	x
Test Questionnaire about driving (in lane positioning)		x				x
Test Questionnaire about LDW						
- ease of use						
- ease of use (learning and familiarity)						
- Trust						
- User practice						
- Travel Patterns						
- System effects						
- Usefulness						
- Misuse						
- Effectiveness						
- Satisfaction						
LDW system description						x
Acceptance of LDW - Extended Van Der Laan						
Social acceptability						x
Willingness to pay - Affordability						x
Advices to designers						
Debriefing - Overall system evaluation						
Debriefing - Study evaluation						x

Figure 5. Italian FOT questionnaire arrangement for Control Group

TEST PLANNING AND EXPERIMENTAL PROCEDURES

The driver liaison centre of EuroFOT Italian test site provides support and all information about the project to participants. In particular, a specific phone number and an email address are available for drivers that want information about questionnaires and how to fill in them.

On line tool (i.e. Limesurvey) will be used for data entry procedures in order to translate in digital form the manually filled paper-based questionnaires. All data collected through questionnaires will be inserted into a data server and properly analyzed using the identified statistical algorithms. According to EuroFOT consortium, a detailed Data Analysis Plan has been fixed. Preliminary results concerning user acceptance and user-related aspects of the systems, the impact analysis and the Cost-Benefit Analysis (CBA) will be defined during 2011.

As already described, FOT experimental design includes a within subjects analysis with a baseline and a LDW treatment period and it also includes a between subjects analysis ensured by the Control Group (i.e. drivers of Lancia Delta car without LDW system).

Type of vehicle	Passenger cars.
Location	National. All Italy.
Road types	All types of roads.
Number of vehicles	About 500 (including Control Group).
Drivers recruited by	Lancia direct contact.
Drivers recruited from	New owners of Lancia Delta equipped with Driving Advisor optional feature (LDW system). New owners of Lancia Delta without Driving Advisor optional feature (Control Group).
Incentive	Fuel bonus.
Pre selection criteria	Contact letter and screening questionnaire to check drivers' travel patterns.
FOT start	From February 2010.

Table 1. FOT overview

PRELIMINARY RESULTS

The complete set of test results will be available at the end of the project planned at the end of 2011 (1). Final results will present the detailed delivery of data and responses from questionnaires and the test of research hypotheses according to the Data Analysis Plan.

Preliminary results about Italian FOT status involving the recruitment process, questionnaire administration and response rates are presented hereafter.
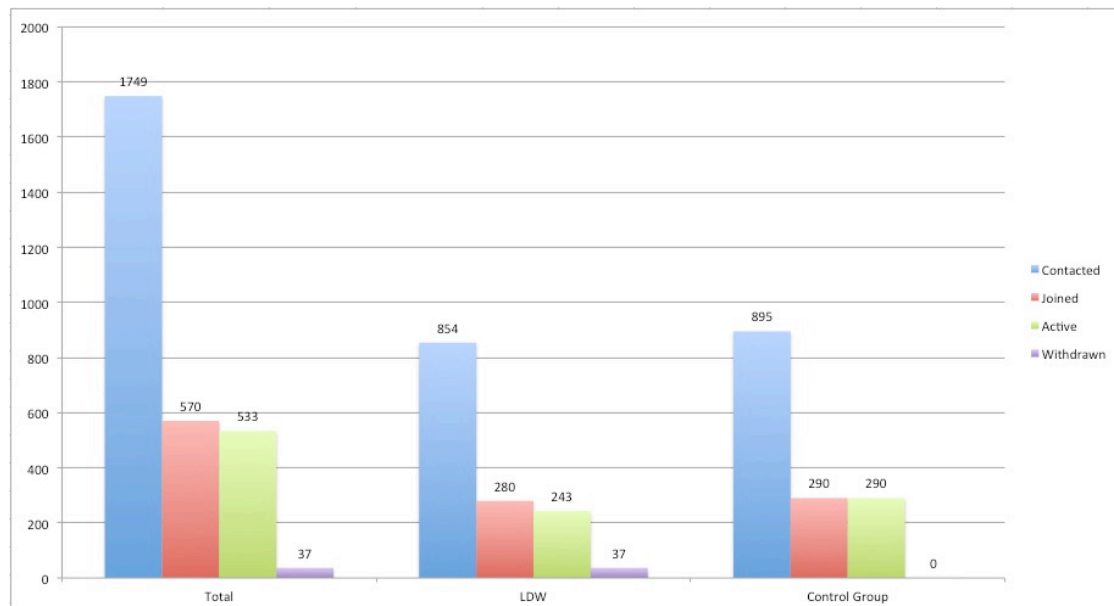
last update: 01-04-2011	Total	LDW	Control Group
Contacted	1749	854	895
Joined	570	280	290
Active	533	243	290
Withdrawn	37	37	0

Table 2. Recruitment status
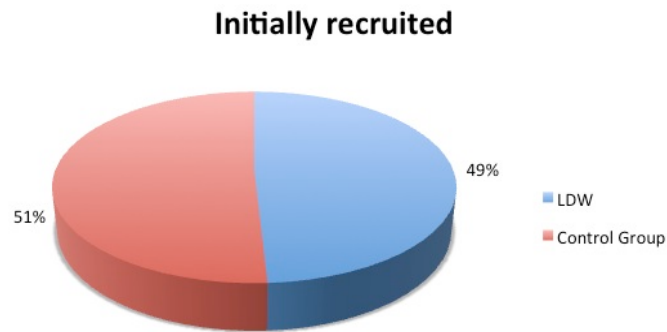
Figure 6. Sample distribution between LDW Group and Control Group

Figure 7. Recruitment overall chart

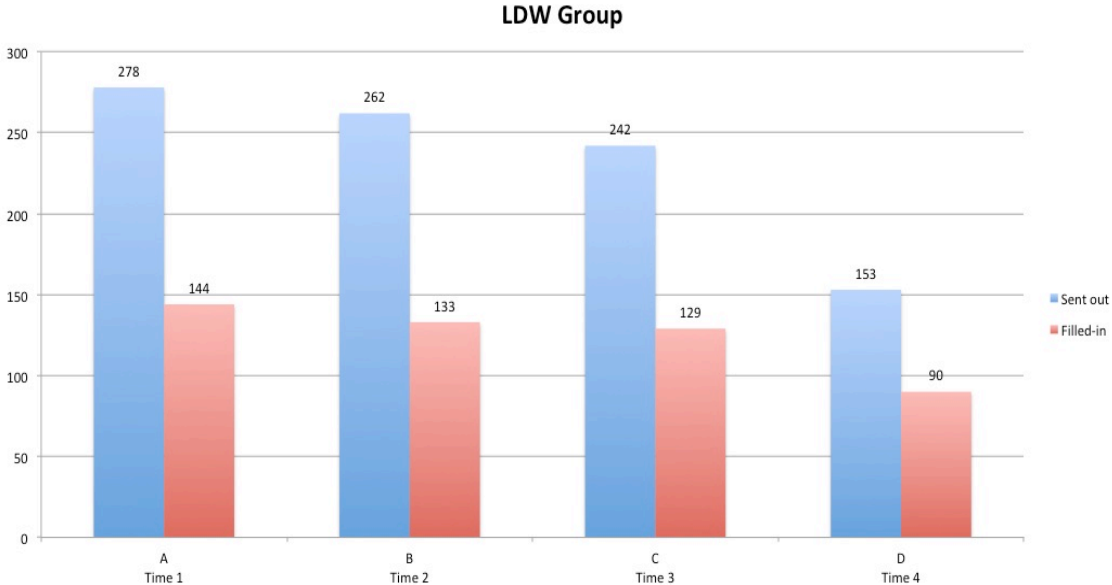|	Total	LDW Group	Control Group
Joing the project (in relation to the contacted customers)	32,59%	32,79%	32,40%
Active (in relation to project participants initially recruited)	93,51%	86,79%	100,00%
Withdrawn (in relation to project partipants initially recruited)	6,49%	13,21%	0,00%

Table 3. Recruitment rates

The number of customers joining the project (590) is 32,59% of the overall number of contacted customers (1749). The number of project participants actually active (533) is 93,51% of total project participants initially recruited (570). The number of project participants withdrawn explicitly, that is those who dropped-out after their agreement in the project participation (37), is 6,49% of total project participants initially recruited (570).

The number of LDW Group project participants initially recruited (280) is 32,79% of total LDW contacted customers (854). The number of LDW customers explicitly expressing their not consensus in participation at contact time (27) is 3,16% of total LDW initially contacted customers (854). The number of LDW Group project participants actually active (243) is 86,79% of total LDW Group project participant initially recruited (280).

The number of Control Group project participants initially recruited (290) is 32,40% of total Control Group contacted customers (895). The number of Control Group project participants actually active (290) is 100% of total Control Group project participant initially recruited (290).

| last update: 01-04-2011					
LDW Group					
	Total	**A** **Time 1**	**B** **Time 2**	**C** **Time 3**	**D** **Time 4**
Sent out	935	278	262	242	153
Filled-in	496	144	133	129	90
Response rate	53,05%	51,80%	50,76%	53,31%	58,82%
Weekly	206	71	54	45	36
Event	48	33	10	5	0

Table 4. LDW Group response rates

Figure 8. Status of administration and gathering of questionnaires for LDW Group

last update: 01-04-2011				
Control Group				
	Total	**A** **Time 1**	**B** **Time 2**	**C** **Time 3**
Sent out	523	175	175	173
Filled-in	432	145	141	146
Response rate	82,60%	82,86%	80,57%	84,39%

Table 5. Control Group response rates
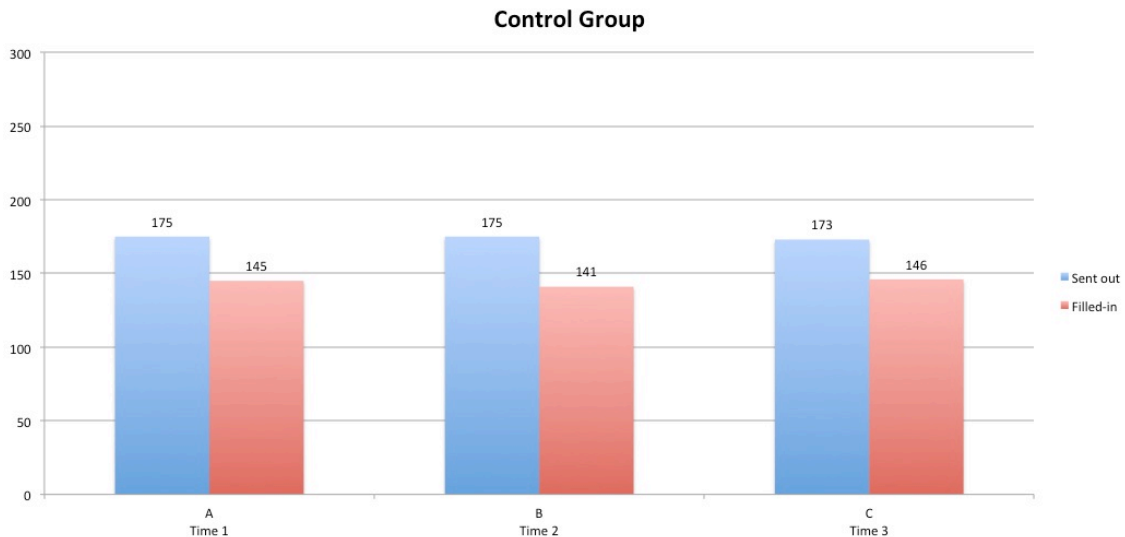
Figure 9. Status of administration and gathering of questionnaires for Control Group

LESSONS LEARNED

Some lessons learned can be pointed out about FOT operational procedures and methods. They concern driver recruitment, driver liaison centre, day-by-day activity for a large-scale test, data management tools and piloting test phases. These lessons learned are being highlighted during the on-going operational procedures of the Italian test site of EuroFOT project and they should be taken into account also regarding to the subjective Field Operational Test carried out. The main lessons learned from Italian FOT are listed hereafter.

- Incentives could help to increase a lot the recruitment ratio, but it seems to be almost impossible to reach very high percentages (e.g. more than 90%) with relatively high incentives.
- Withdrawals are mainly before to answer the first questionnaire. This questionnaire is also the heaviest one in terms of number of questions. A more balanced distribution of questions, with a lighter first questionnaire, could help to reduce this number of withdrawals.
- Contact material for drivers recruiting is very important to maximize response rate.
- It is very important to highlight the research aims of the whole project while recruiting drivers. Piloting phase is crucial to improve these procedures and highlight the most

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effective contact protocol, therein including wording.

- Pre-screening of customers impact on final recruitment and participation rate. Recent customers of new vehicles seem to be more sensitive to be involved in transport safety initiatives than experienced owners.
- Continuous tasks, for example to register events during driving, are very difficult to be well performed, compared with the discrete task to fill questionnaires in.
- In order to reach more drivers and improve response rate, it is very good to duplicate or offer multiple options for filling questionnaires in (i.e. hard copy and electronic copy).
- Pilot tests should provide feedback concerning the whole experimental design and the practical issues. The FOT could be deeply revised after pilot results.
- When preparing questionnaires to be used in different countries, translations and related validation should be considered from the very first draft.
- It is very important to develop and improve a web-based survey tool for data collection in order to save time and prevent data transcription mistakes.
- It is very important to improve and share driver liaison centre procedures in order to provide the best support as possible to project participants.
- It is very important to get in touch with project participants, in order to ensure data collection, but this has to be done case by case, since some driver could be disturbed by that. Any request has to be timely answered.
- A link to the OEMs customer services has to be established from the beginning, since customers could use the survey also to send questions that are not related to the project itself, but to the vehicle.

CONCLUSION

This FOT will permit an accurate investigation and understanding of the impact of LDW system in respect to several subjective aspects such as perceived safety, usefulness, acceptance, driving behaviours and subjective mental workload. This statistically significant assessment would offer to OEM, stakeholders and researchers the possibility to consider the results of this analysis not only limited to a restricted number of subjects but extendable to the drivers' universe as a whole. The complete results will be available at the end of the project, planned during 2011 (1).

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