INVESTIGATING THE IMPACT OF A LANE DEPARTURE WARNING SYSTEM IN REAL DRIVING CONDITIONS - A SUBJECTIVE FIELD OPERATIONAL TEST

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ABSTRACT: This paper presents the Italian Field Operation Test (FOT) to be performed within the European project euroFOT aimed at assessing a wide variety of Intelligent Transport Systems (ITS) across Europe. The Italian FOT in euroFOT is aimed at investigating the Lane Departure Warning system (LDW) equipped on Lancia Delta vehicles, deploying a sample of up to 300 vehicles and using a wide and differentiated set of self-reported questionnaires. Based on subjective responses, objective measures will be constructed using psychometric methods and models. Results will assess subjective user-related aspects and will be referred to LDW impact on driving safety, user acceptance of the system, usefulness and driving behaviour. Because of the psychometric methodology adopted, results are expected to accurately depict the actual impact of this function.

1. INTRODUCTION

1.1 Field Operational Test

The Intelligent Car Initiative (ICI) has identified road safety, energy, efficiency and traffic congestion as the main challenges currently facing European transportation. Despite their severity, these issues may be improved with the use of new in-vehicle technologies recently made available in the market.

Intelligent Transport Systems (ITS) – including both safety and telematic 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 traffic safety, markets' and users' acceptance are difficult to assess alone from internal testing.

Moving from this preamble, European Commission launched - within the Seventh Framework Programme (FP7) for research and technological development – a large programme of Field Operational Tests (FOT) where

benefits of ITSs towards traffic safety and users' acceptance will be largely tested. In this context, euroFOT research project started (http://www.eurofot-ip.eu) with the main aim to demonstrate the effectiveness and encouraging the deployment of intelligent vehicle systems on European roads.

1.2 euroFOT project

During the course of 2010, over 1000 vehicles will be tested from 9 European OEM brands. Several test centres will be set-up across France, Germany, Italy and Sweden [1]. The goal of euroFOT project is to identify and coordinate an in-the-field testing of ITSs with the potential for improving the quality and safety of European road traffic. euroFOT consortium has brought together 28 different organizations across Europe (e.g. car manufacturers, suppliers, universities, research institutes and others stakeholders) [1].

In details, 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 FESTA project [2].

1.3 Functions to be tested in euroFOT project

Different field testing are expected in this project, focused on 8 distinct functions. In particular: driver assistance in forward/rear longitudinal control functions (i.e. Adaptive Cruise Control, Forward Collision Warning, Speed Regulation System), in lateral control (i.e. Blind Spot Information System, Lane Departure Warning and Impairment Warning), and finally other advanced applications such as Curve Speed Warning, Fuel Efficiency Advisor and Safe Human-Machine Interface [1].

The project will follow three major steps. In the first, the fleets are being prepared for the trials specifying the functions, defining hypotheses for each of the functions, setting up data management procedures, and recruiting the drivers' samples. Secondly, involving the installation of data loggers and functionalities into the vehicles. Finally, analyzing data collected from the vehicle monitoring devices and from the driver himself (the so-called objective and subjective data).

2. TESTING THE LANE DEPARTURE WARNING

This paper is focused to describe and highlight the preliminary results of the Italian test site in the framework of the euroFOT project. The test will investigate the LDW function available on the Lancia Delta (see Figure 1), namely the Driving Advisor. In the euroFOT project, other test sites (i.e. German 1 and Sweden test sites) will also test LDW function using a different experimental method [1].

Fig.1. Lancia Delta

2.1 Lancia Lane Departure Warning system

This ADAS (i.e. Advance Driver Assistance System) solution available on the Lancia Delta, with the market name of Driving Advisor, provides a feedback to the driver through a torque applied on the steering wheel as soon as the driver unintentionally is going close or overcome a lane border, when the proper indicator is not activated (see Figure 2). This system uses a small camera mounted on the rearing mirror to acquire images of the road in front of the vehicle, then measuring the vehicle position relatively to the lane borders.

Fig. 2. Lancia Lane Departure Warning system

2.2 Design of Experiment and questionnaires

Italian FOT in the euroFOT project has the objective to select up to 250 customers/drivers of the LDW system and follow them in the first period of use, i.e. 9 months [1]. During such period, drivers will provide their feedback answering specific questionnaires or filling forms related to specific events that happened during the vehicle usage and their subjective evaluation about the LDW system.

The use of subjective data does not guarantee the same level of reliability provided by objective data gathered from data loggers. Nonetheless, given the aims of this project, the use of self-reported questionnaires is indicated 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 (see Figure 5). Therefore questionnaires have been planned 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 items related to LDW system use will be not administered to them. 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.

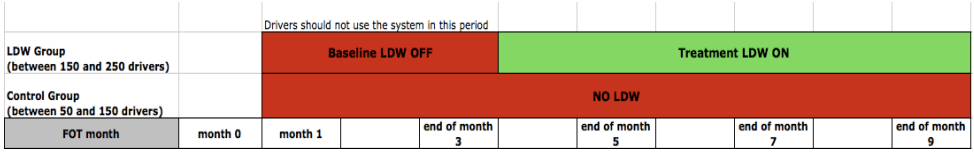

Fig. 3. FOT Design of Experiment

About experimental procedures, five questionnaires are planned (see Figure 4). They are directed to the vehicle main user. The first one is an introductory questionnaire in which the major social and demographic characteristics of drivers, including their driving habits, attitudes and behaviours will be collected. Some standardized tools could be used to register these drivers' characteristics. The Driving Behaviour Questionnaire (DBQ) 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 [3]. The questionnaire will be filled in by drivers as soon as they accept to participate to the project, well before, if possible, to get the vehicle.

A specific section of the first introduction questionnaire could register the risk perception of the drivers facing them with a explained contest and asking how often they engage in a behaviour like that or how likely they are getting in an accident while doing that. That section is called Sensation Seeking questionnaire [4]. Another standardized tool that will be used in the second

questionnaire is the Driving Style Questionnaire (DSQ) that examines how drivers usually behave in specific situations [5].

Other questionnaires will be filled in by drivers every 2 months. These questionnaires will detect users' perception about safety, trust, effectiveness, usefulness and value of the Driving Advisor, in strict accordance with the FESTA project research hypotheses referred to these functions, and the corresponding performance indicators, i.e. the quantifiable way to detect how these hypotheses can be assessed [2].

In the periodical questionnaires the drivers will be asked to fill in a specific post test questionnaire section. These questionnaires aim to detect the viewpoint of the user about some aspects of the LDW function like 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 in the last period [6]. A specific section in the periodical questionnaires is dedicated to the drivers' acceptance using Van Der Laan scale to register the usability of the system [7]. The risk perception of the drivers is also registered.

A weekly vehicle normal use register will be also provided in order to detect and manage data about drivers' car use during the FOT execution. Drivers will be asked to fill in a form and register some data as how many kilometres they did in the last week and what was the average speed in that period. A board diary is finally planned to detect driver particular perception about LDW in a specific scenario, type of road, driver status and also the description of the event and the state of the system.

Participants' responses to questionnaires will be treated using Item Response Theory (IRT) models, which permit to generate measures from subjective responses [8].

This assessment has been defined in strict accordance with the FESTA project research hypotheses referred to these ITSs functions and the corresponding performance indicators, i.e. the quantifiable way to detect how these hypotheses can be assessed [2].

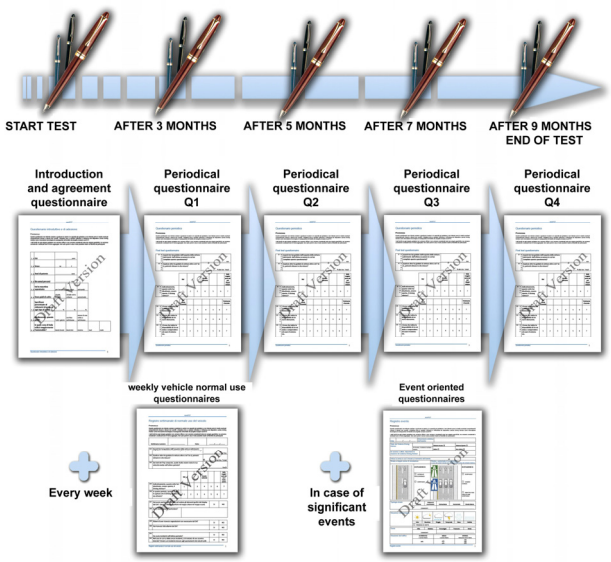

Fig. 4. Questionnaires planning and timing at a glance

2.3 Testing of research hypotheses

The euroFOT project defined and prioritized research hypotheses for each function that will be tested. These hypotheses have been derived from FESTA project [2] and from the consultations between intelligent transport system experts performed in the framework of euroFOT activities [1]. These hypotheses are derived also considering system specifications and use cases.

The top research hypotheses defined about LDW function are briefly reported in the following. Does the LDW decrease and mitigate incidents, near-crashes, and accidents? Does LDW influences lateral driving performance? Does it increase the use of turn indicators in lane changing situations? Does LDW usage increase more and more over time? Does LDW increase night driving? Does LDW lead to an appropriate driver reaction? Is LDW well accepted by the driver? Does LDW acceptance/adoption increase with LDW usage?
According to FESTA project, even performance indicators have been defined in the methodological framework of euroFOT to test the hypotheses (see Figure 5).

In the test of Lancia LDW the repeated rounds of questionnaires will highlight changes in users' perceptions over time and, according to the Design of Experiment defined, allow analysts to test the hypotheses.

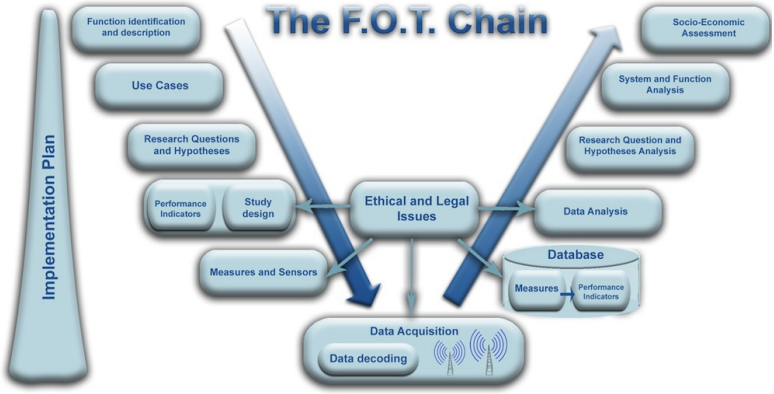

Fig. 5. The FOT chain defined in FESTA project [2]

2.4 Test planning and experimental procedures

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).

The first draft of the questionnaires has been developed during 2009 and now is going to be updated and fixed. A help desk contact (i.e. driver liaison centre), which provides support and all information about the project, has been set up. 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 also used 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, the preliminary results concerning user acceptance and user-related aspects, the impact analysis and the Cost-Benefit Analysis (CBA) will be defined at the beginning of 2010. The guidelines and the Data Analysis Plan will be fixed during 2010, based on the piloting outcomes (see Table 1 and Figure 6).

Table 1 – Piloting overview

Piloting tests start	Since October 2009.
Number of vehicles in Piloting tests	10 vehicles with LDW recruited by Fiat. 10 vehicles as piloting Control Group without LDW recruited by Fiat.
Duration of Piloting test	3 months. Submission of introduction questionnaire and some periodical questionnaires to test core items.
Piloting drivers recruited from	New owners of Lancia Delta equipped with Driving Advisor optional feature (LDW system).

LDW Group (10 drivers)		Treatment LDW ON		
Control Group (10 drivers)		NO LDW		
FOT month	month 0	month 1	After 15 days	End of month 1
Timing	First Contact	PILOT start		Pilot End
Questionnaire	Contact letter - Screening questionnaire	A Pilot + Weekly + Event	C Pilot	E Pilot
Sending Date	12-10-09	26-10-09	09-11-09	25-11-09

Fig. 6. - Piloting experimental design and timing of Piloting questionnaires

After piloting review of questionnaires and test of every operational procedure, the FOT will start with the recruiting ramping up phase (see Table 2 and Figure 7). Questionnaires will be administered as defined above. As already described, FOT experimental design includes a within subjects analysis with a baseline and a LDW treatment period and it also includes a Control Group (i.e. drivers of Lancia Delta car without LDW system) to ensure a between subjects analysis.

Table 2 – FOT overview

Type of vehicle	Cars.
Location	National. All Italy.
Road types	All types of roads.
Number of vehicles	Up to 300 (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).
Incentive	Fuel bonus.
Pre selection criteria	Contact letter and screening questionnaire.
FOT start	From February 2010.
Control Group	New owner of Lancia Delta without LDW system.
Number of Control Group vehicles	About 150.

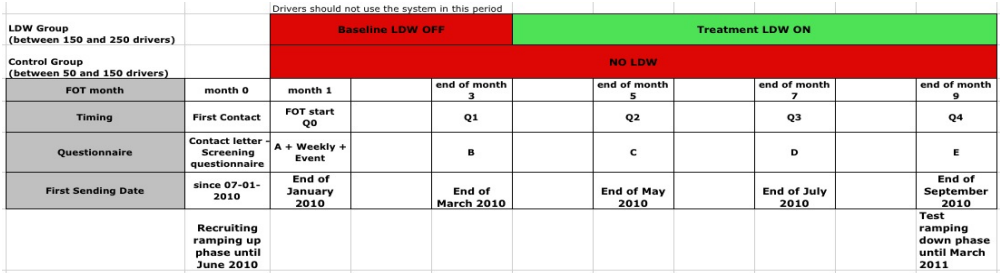

Fig. 7. - FOT experimental design and timing of FOT questionnaires

3. 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 in 2011 [1].

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