Impact evaluation of speed regulation systems using naturalistic driving data: The EuroFOT example

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Abstract

The goal of this paper is to present the work done by IFSTTAR and CEESAR during the first large scale field operational test in Europe: the EuroFOT project. During the project duration, the FESTA methodology has been applied in real conditions for the first time, in order to evaluate 8 different mature driving assistance systems. The French partners were in charge of performing an impact assessment of the speed regulation system, which is a bundle of two different functions: speed limiter, and cruise control. In this paper, we present the overall process of performing such an evaluation using naturalistic driving data coming from 35 drivers from Paris region. We provide the reader with technical, practical, and methodological aspects, with a focus to the lessons learned. The general conclusion takes profit from the results to determine the best practice for evaluating the impacts of a longitudinal driving assistance system.

Keywords: Speed limiter; Cruise control; road safety; impact assessment; naturalistic driving; safety events; Field Operational Test, driving assistance systems.

Résumé

Ce papier a pour objectif de présenter les travaux effectués par l'IFSTTAR et le CEESAR dans le cadre du projet EuroFOT, le premier grand FOT européen. Dans ce cadre, l'ensemble de la méthodologie FESTA a été appliquée pour la première fois en conditions réelles, avec pour objectif d'évaluer 8 systèmes matures d'aide à la conduite. Les partenaires français avaient la charge de mener une étude d'impact multicritère du système de régulation de vitesse constitué du limiteur et du régulateur. Nous présentons dans cet article le processus complet de mise en oeuvre de cette évaluation reposant sur l'observation en conditions naturelles de 35 conducteurs de la région parisienne. Nous détaillons les aspects techniques, pratiques, et méthodologiques, ainsi que les leçons retenues. La conclusion générale s'appuie sur les résultats obtenus pour essayer de déterminer les bonnes pratiques pour l'évaluation d'un système d'aide à la conduite agissant sur la vitesse.

Mots-clé: Limiteur de vitesse; régulateur de vitesse; sécurité routière; évaluation; conduite en situation naturelle; incidents; systèmes d'aide à la conduite.

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1. Introduction

Thanks to recent progresses in IT and vehicle technology, large fleets can now be instrumented to collect data for different purposes. Naturalistic Driving Studies (NDS) and Field Operational Tests (FOT) both use equipped subject's own vehicles to continuously collect driving data during a time period long enough to avoid experimental bias. The EuroFOT project, ended in 2012, was the first European large scale FOT to take profit from this methodology to assess the global impact of driving assistance systems in real conditions (public deliverables are downloadable from http://www.eurofot-ip.eu). The authors of this paper were in charge of leading the French part of this project, from data acquisition, to impact on traffic safety, acceptance and user related aspects. The French partners focused on evaluating the speed regulation systems, known as the speed limiter (SL) and the cruise control (CC). This work recall the main results obtained both for safety and system use, with the help of quantitative and subjective collected data.

First, the data collection practical issues are presented, from data management software's developed to deal specifically with large databases containing probe vehicles data, to the original experimental plan. Preparation of the data for further statistical analyses is another important point to deal with. This paper summarizes the treatment applied to the data, and the data reduction technique used. Safety impact assessment for both SL and CC makes use of automatically identified safety related events (hard braking, over-speeding, etc.), and knowledge about driving conditions (speed limit, weather, curves, crossings etc.). It is first highlighted that SL and CC usage are impacted by adverse driving conditions in a different way. It is also demonstrated that safety related events are less probable when SL or CC are activated. Quantitative results are confirmed by subjective information obtained using questionnaires. The methodological aspects are the focus of the work, and we highlight the need to use suitable statistical models to fit the naturalistic driving context characterized by driver-specific correlations and repeated measurements. Among the suitable models, it is chosen to use Generalized Linear Mixed Models (GLMM) to assess the systems impacts on safety events probability of occurrence. Model performances are discussed and different confounding effects are analyzed (speed limit etc.). A final discussion explores different ways to improve data selection, and hypotheses answering in the framework of the FESTA methodology (2008).

2. EuroFOT project description

The euroFOT project was the first large-scale Field Operational Test (FOT) of multiple Advanced Driver Assistance Systems (ADAS) in Europe. It evaluated the impact of eight different ADAS on safety, traffic efficiency, environment, driver behaviour and user-acceptance in real life situations by collecting data from instrumented vehicles. Offering valuable information for the short- and long-term impact of ADAS, the euroFOT project aimed to encourage their wide deployment. Altogether, about 1000 vehicles equipped with different ADAS technologies took part in the field operational test. The FOT was coordinated by five Vehicle Management Centres (VMC) and carried out at various operation sites across six European countries (France, Germany, Italy, Netherlands, Sweden and United Kingdom). Nevertheless, drivers could use their vehicles in different countries across Europe. The following functions were investigated:

- Longitudinal functions: Adaptive Cruise Control (ACC) and Forward Collision Warning (FCW) together in one bundle (together counted as one function) and Speed Regulation System (SRS) composed of Speed Limiter (SL) and Cruise Control (CC).
- Lateral functions: Lane Departure Warning (LDW) and Impairment Warning (IW) together in one bundle for passenger cars (together counted as one function for passenger cars) and Blind Spot Information System (BLIS).
- Other functions: Curve Speed Warning (CSW), Fuel Efficiency Advisory (FEA) and navigation systems (SafeHMI).

The analysis was conducted at each VMC according to the data analysis plan previously elaborated in the project, with some specificity depending on the evaluated system. The data collection phase was conducted for 12 months at most VMCs. The first three months were used as a baseline phase when the tested functions were deactivated. In the remaining period the functions could be used by the drivers without restrictions (treatment phase). The impact assessment was conducted by comparing the relevant performance indicators between the baseline and treatment phase.

3. French VMC – Operation site CEESAR

The French VMC consisted of a single Operation Site. It was located at CEESAR's premises, west of Paris. CEESAR handled all aspects of the experiment's organization: - recruitment and contracting of drivers - vehicle instrumentation and questionnaires data - data processing and quality monitoring, and - troubleshooting of data acquisition systems.

3.1. FOT vehicles

Two different vehicles families were used: Renault Clio III and Renault Laguna III. All body styles were accepted, and participated in the project (sedan, estate, coupé…). Cruise Control and Speed Limiter is standard in all Laguna vehicles, and equips an important share of all Clio sold. Although Cruise Control is a very common driving assistance system, Speed Limiter is rarer. Speed Limiter limits the engine throttle when a longitudinal speed, which is chosen by the driver, is reached. This limitation can be overridden by fully pressing the throttle pedal. Cruise Control and Speed Limiter are integrated together in a common human-machine interface, resulting in a single *Speed Regulation Assistance System* with two user-selectable modes: Cruise Control and Speed Limiter.

3.2. Instrumentation

CEESAR designed a modular data acquisition system based around a CTAG datalogger, an optional, custom-made video logger, and external sensors. Two instrumentation levels were used in the experiment. Participants' own vehicles were fitted with a CTAG datalogger and additional long-range radar. Five CEESAR owned cars also included 4-channels video logging, eye tracking and lane tracking devices (cf. Table 1 below).

Table 1: French VMC datalogger instrumentation levels

	Low Level	**High Level**
Vehicles used	35 drivers' owned vehicles.	5 vehicles owned by CEESAR and loaned to participants
CTAG datalogger 2	●	●
Max 4 CAN Channels	2 channels used	4 channels used
GPS	●	●
GPRS data transfer	●	*(not used : manual transfer)*
TRW AC20 radar *(not part of standard vehicle equipment)*	●	●
VideoLogger *(custom made for CEESAR, H.264)*		●
Cameras *(B&W, SuperHAD Exview)*		4
Mobileye AWS *(added, with special firmware)*		●
Smarteye Eyetracker		●

4. The implemented experimental design and the FOT operation

For each driver, the FOT took 12 months in total. For most of the time during the FOT, the participants were driving their own cars, interrupted by three short periods during which participants were being given one of the five CEESAR vehicles. The CEESAR vehicles with 'high level' instrumentation were rotated among the drivers (Clio drivers were loaned a Clio, and Laguna Drivers a Laguna). Two experimental conditions are compared in the particular French experimental design (see Figure 1, for an overview):

- Baseline condition: Driving without using the systems of interest (SL and CC are off). For each driver, this included ten weeks with his/her own car with "light instrumentation", and two weeks with one of CEESAR's fully instrumented cars.
- Test condition: Driving with the systems SL and CC. This period included two 2-weeks periods using a fully instrumented car by CEESAR in-between the test period and at the end of the test period.

Questionnaires were provided to drivers using a LimeSurvey operated web server. Each time he had to fill a new questionnaire (after the baseline period, in the middle of the experiment, and at the end of the experiment), a driver received an Email with a personal link to fill it in. The initial experimental plan was to instrument the

vehicles by waves of 5 drivers (3 Laguna III and 2 Clio III). 7 waves of 5 participants were planned for the 35 participants. Because of the difficulties met with the recruitment of Laguna III drivers, the first vehicles were instrumented in November 2010 and the last ones in June 2011.

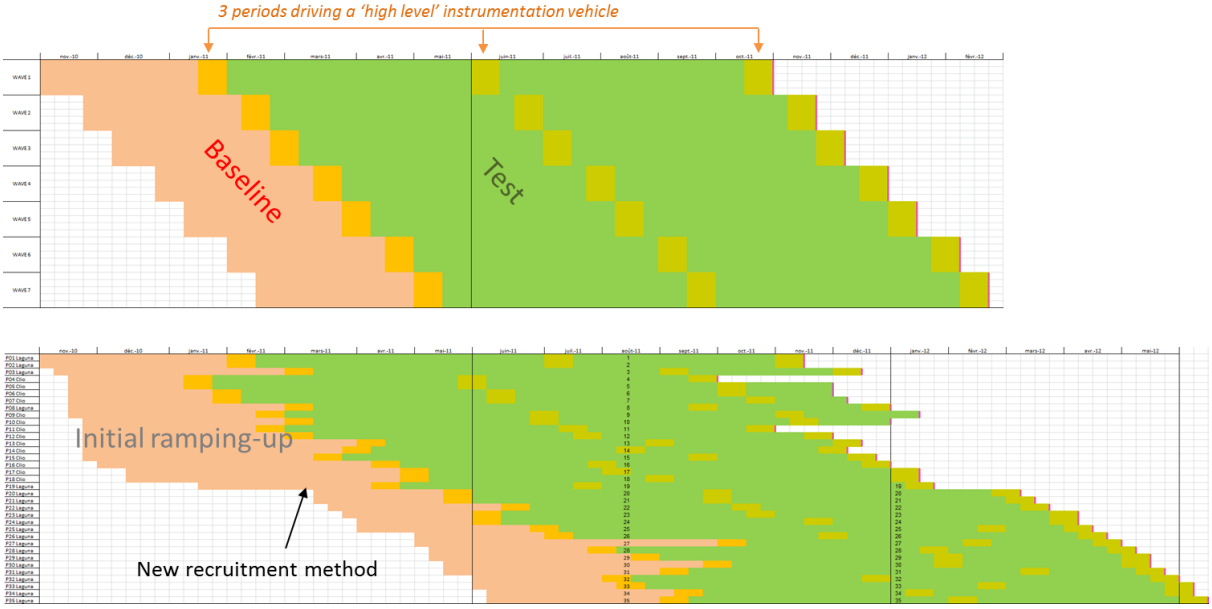

Figure 1: Ideal and actual experiment organization

Staggering of the recruitment and participant-related constraints did not allow keeping the initial experimental plan. Consequently, rotation of 'high level' instrumentation vehicles between drivers was constantly adapted in order to match participants and vehicles availabilities (see Figure 1). For each of the participants it was tried to stay as close as possible to the optimum plan, and avoiding any additional delay in the execution of the FOT. This proved to be a very complex and time-consuming process.

4.1. Results of the FOT operation phase

At the end of the experiment, **545 340 km** and **12 590 hours** of data were collected, processed and used for analysis. Let us remark that a total of 581000 km of data were collected right until the end of the project, but the very last 35 000 km could not be included in the current analysis. All data have CAN, GPS, and additional RADAR, with the exception of 180 hours of data where we had a Radar failure. **1522 hours** of data correspond to a 'high level' instrumentation, with video, lane tracking and eye tracking. Thanks to an efficient video compression (h.264) being done directly in the vehicles, the complete raw dataset fits in **1 TB**. Derived data takes an additional **0.5 TB**.

4.2. Lessons learned

Figures show that even without very strict inclusion criteria, 20 drivers, for which we already knew that they owned and drove an appropriate vehicle, had to be contacted to recruit each final participant. This shows how challenging recruitment can be, especially in the case when either the ADAS studied, or the vehicle itself, doesn't sell in large quantity. As a result and even if this generally has a cost, we learnt that getting direct access to nation-wide car owners' databases is necessary to ensure an efficient recruitment. Conversely, local recruitment through car dealers required a lot of efforts to motivate them and get their help, for comparatively deceiving results. The data transfer with embedded GPRS modem also proved problematic. Network coverage and transfer rates were generally insufficient to ensure that all data could be transferred while vehicles were driven. Hence, for future projects, we would recommend using more modern transfer protocols (e.g. UMTS), to allow better transfer rates, and perform on board calculation of quality indicators, which could easily be transferred even with poor bandwidth. Although it proved problematic for a few drivers, online questionnaires were generally a very efficient solution. The experimental plan which had been adopted (i.e. the rotation of 'high level' instrumentation vehicles between drivers) resulted in a very complex organization because the FOT was started before all participants were recruited. Therefore, such an experimental plan should be avoided, in favour

of a much simpler "instrument and forget" approach. Also, although participants gave very high grades to the organization, results of the debriefing questionnaire show that topics in relation with the system studied itself (Cruise Control / Speed Limiter) could have maybe been better handled. This demonstrates that, regardless of the complexity of the organization, extreme care has to be given to more 'scientific' matters such as training on the studied system.

5. Data management

For easier use of the suitable statistical models, and for data reduction issues, it has been decided to aggregate the data following the approach named "chunking" and proposed by Dozza et al. (2012). Chunking the data consist in splitting the trips according to certain values of situational variables. At the French VMC, in order to be able to study certain features of the SRS system, we have decided to keep constant among a chunk the following variables: TripID, DriverID, road type (Urban, rural, motorway), speed limit (30, 50, 70, 90, 110, 130 km/h), weather (dry or rain), and lighting (night or day). Moreover, for comparison purposes, the chunks are also sliced in 30 sec. sections. The process ends by obtaining thousands of 30 sec. chunks each one of them being descripted by a list of performance indicators (PI). Chunks are characterized by these performance indicators set, leading to a final chunk table with as many lines as different chunks, and as many columns as PI computed. Chunks are selected differently according to the research hypothesis. Criteria may vary according to the system studied, or to selection choice.

Driver speed choice is highly dependent on the road design. An high correlation is expected between speed limit, road type, and average measured speed, and there is a need to carefully choose baseline and treatment data. If CC is only used on motorways, then the baseline to evaluate effect on speed does not need to incorporate urban data. There is a need to make the exposure information (i.e. road type or speed limit encountered by the driver) comparable between experiment and baseline. Following Guo & Hankey 2009, we adopt a total baseline random sampling scheme: For each driver and for each exposure condition (i.e. speed limits), we sample as many kilometers from the baseline as in the treatment data. For example, if driver "i" has traveled during 2% of the total distance collected during treatment, then 2% of the baseline sampling should correspond to this driver.

6. Safety impact assessment available methods for SRS

6.1. Speed & accident relationships

There have been a considerable number of studies looking at the relationship between the speed choice of car drivers and crash risk. From the observed speeds and accident data acquired in these studies, a variety of statistical relationships or models relating speeds to crash risk have been calculated. The authors followed Carsten et al. (2008), and reviewed these models and identified those that were best suited to being applied to predicting the impact of SL and CC on crash risk (see Table 2 for a summary). Preferred models were identified for each speed limit. Criteria for model selection included that they should be appropriate theoretically for a system such as SRS which tends to curtail high speeds and that they should be based on data that covered the relevant speed limit.

Table 2: Speed & Accident candidate models to evaluate changes in accident frequency.

Model	Reference	Road type	Model parameters	Model
U2	Taylor et al, 2000	50-70 km/h	AF=Accident frequency, P=% of traffic above speed limit, S_{ex}=Average speed of traffic exceeding speed limit, K_{U2}=constant	$AF = K_{U2} P^{\gamma} e^{\lambda S_{ex}}$
Power model	Elvik et al., 2004	90-110 km/h	Av. speed after, av. speed before, M is the metric of interest	$M_{after}/M_{before}=(Speed_{after}/Speed_{before})^{Power}$
Kloeden rural	Kloeden et al., 2001	130 km/h	S=relative driving speed	$RR(V) = \exp(0.07039 \times S + 0.0008617 \times S^2)$

The main drawback of such models is that they do not include traffic environment variables such as traffic density. For example, if a function mainly is used in low traffic densities—which is expected for CC— then an increase in average speed would not necessarily lead to an increase in average risk (which the models would

predict), since risk is moderated also by traffic density. U2 model is very interesting for SRS evaluation because it relates to the proportion of drivers exceeding the legal speed instead of the average speed. Over-speeding events can easily be identified in the data, and therefore, the odd ratio for such an event represents the expected increase in the proportion of drivers exceeding speed if 100% of drivers were using the system. Results of this approach are presented at section 7.5.

6.2. event based analysis

The basic principle of EBA in a FOT context is to identify time segments (events) thought to be predictive of crash involvement, and then compare the frequency of these in baseline (where no ADAS is present) and treatment (where an ADAS is present). Examples of events include situations where the driver performs a violent evasive maneuver, i.e. where the distance in time and/or space from an actual crash is very small. These events can be identified retrospectively in the driving data, together with interaction/confounding factors such as road type, speed limit, traffic conditions, other systems etc., and then either analyzed directly, or studied by for example implementing a simulation in which the events are further varied to explore potential outcomes. EBA analysis applies primarily to ADAS which are intended to reduce the frequency of certain time discrete events directly related to loss of control, such as crashing into a lead vehicle (FCW) or unintended lane departure (LDW). It can also be applied to events more indirectly related to loss of control, or poor longitudinal behaviour such over-speeding or critical time gap. As long as the ADAS influence on driver performance can be described using the occurrence of discrete events, EBA analysis is applicable. Examples of previous studies where EBA analysis has been applied are discussed in Dingus et al. (2006), Trent et al. (2010), or Blanco et al. (2009). The final step is to interpret this difference between baseline and treatment in terms of influence on the target crash population. First, there is the issue of size and significance of an identified difference. To test this, many different methods described in Guo & Hankey (2009) are available. The simplest form of comparison is to make a contingency table by counting the frequency of events in baseline and treatment conditions (based on some form of exposure normalisation, such as the number of events per driving hour) for each driver to understand, whether ADAS presence causes a change in event frequency.

6.3. Statistical models

In terms of the methodology, a drawback of contingency tables is that it is only possible to consider one factor at a time, and interaction/confounding effects cannot be addressed. Furthermore, contingency tables assume that observations are independent of each other, an assumption which does not suit FOT data very well, as it will contain unavoidable driver-specific correlations (i.e. some drivers will experience more events than others).

To study interacting/confounding factors and to account for these driver specific correlations, more sophisticated statistical models need to be applied. These models are generalizations of the linear models which have been adapted to a binary outcome, something which suits the EBA analysis division of events into baseline and treatment events well. These models include additional parameters to deal with correlations, and confounding factors are regarded as explicative variables that can be used to predict event probability. One such model is the "Generalized Estimated Equations" (GEE) model, originally developed to model longitudinal data by Liang & Zeger (1986), which assumes that observations are marginally correlated. Another such model is "Generalized Linear Mixed Models" (GLMM). Similar to the GEE model, GLMM assumes correlated observations for the same driver. In addition, GLMM also assumes that there is a random effect associated with each individual driver (i.e. one driver can be associated with higher and another with lower risk of event involvement). This has the additional advantage of allowing to control for a small population of drivers being involved in a large proportion of safety events, something which indeed may become an issue (Dingus et al., 2006). Both GEE and GLMM models can also accommodate multiple risk factors, which allow those factors to be evaluated simultaneously. Indeed, this capability may also be used to evaluate different systems in use at the same time or at different times but with possible interactions. For the final dataset, these models were applied where appropriate, depending on the system tested and the events analyzed. For a more technical and detailed description, see Liang & Zeger (1986) and Guo & Hankey (2009) for a focus on naturalistic driving data. All the results presented in the next section were obtained using SAS® software.

7. Key findings from EuroFOT

7.1. Descriptive analysis

The SRS system is used on demand, according to the driving situations chosen by drivers (see Figure 2). Moreover, drivers tend to use more one of the two systems than the other. The cruise control is often used on motorways or freeways (>= 110 km/h) and speed limiter is often used on all roads except motorways (130 km/h).

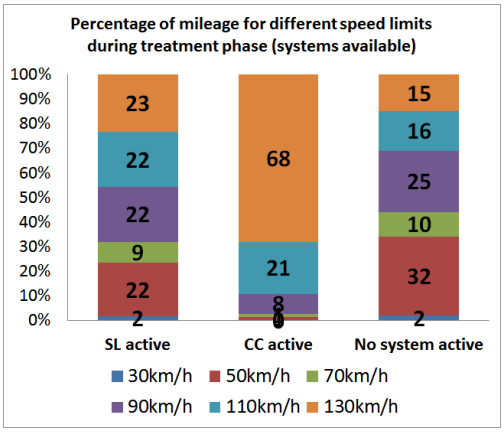

Figure 2: Percentage of mileage for different speed limits during treatment

7.2. Usage

First of all, as the SRS is intended to affect speed behaviour, it is needed to investigate the changes in adopted speeds with and without the system active. EuroFOT results have shown that the average speed increase when SL is used (differences range between 0.75 to 2.33km/h) except on motorways (better compliance with speed limit). The average speed also increases when CC is used. Differences between treatment and baseline are 7.9 km/h on 130km/h roads, and 12.6 km/h on 110 km/h roads. This highlights the usefulness of SRS at high speeds. Figure presents the ratios by which are multiplied the odds of observing an event of interest ("SL is active" and "CC is active" for instance) when binary situational variables are varying from one condition to another. The odds can be viewed as the likelihood of observing the event under a specific condition. For example, when it is raining, the likelihood of using SL is multiplied by 1.4 than in dry weather conditions (odds ratio = 1.4). It is the opposite for CC which is less likely to be used: the likelihood is multiplied by 0.6 (odds ratio = 0.6). The global picture is very different between the two systems. Adverse conditions are generally not favourable to the use of CC (OR below 1 when condition change to an adverse condition), while it is the opposite for SL.

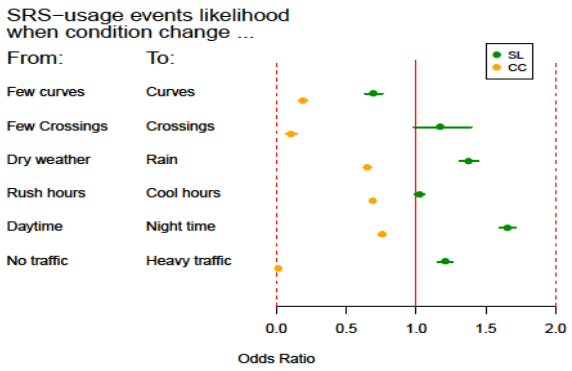

Figure 3: Odds ratios corresponding to the event "SL is active" in green (resp. "CC is active" in orange) for different binary situational variables.

7.3. User acceptance and user-related aspects

With the SL system drivers state that they engage in misuse behaviours only to select a top speed above the speed limit and to use buttons to adjust SL speed instead accelerator pedal. With the CC system drivers state that they engage in misuse behaviours only to select a cruise speed above speed limit and to use CC to overtake a vehicle. For both systems there is no systematic change of workload over the period of system usage.
This experiment allowed us to estimate the acceptance of these systems. The a priori acceptance was already very positive and the use of the systems confirmed this tendency. In terms of usefulness, the opinion of the drivers slightly increased for the SL and strongly for the CC whereas the satisfaction slightly decreased for the SL and increased for the CC. Also, the trust in the system was already positive before its use and during its use, it slightly strengthened for the SL and very strongly for the CC especially in terms of reliability and trust in the system. Both systems were considered very usable by two thirds of the drivers as well in terms of access to visual information, manipulation of the commands and management of the interactions. The only function collecting only half of the positive opinions is the access to on/off button of the system, which is indeed not easily accessible in both vehicle types used for the experiment. In term of comfort, a third of drivers did not report change for the SL, half reported an increase and the others a decrease. In terms of pleasure to drive, the proportion of positive change is lower (35%) and that of negatives is more important (37%). It is true that the SL does not lead a lot of change in the driving because it intervenes only to prevent from exceeding a given speed.
This can lead to inconveniences in certain situations (for example, during insertion on a motorway if the driver forgets to change the speed of the system). For the CC, opinions of the drivers are much more positive: 80% report improved comfort, and 62% report improved pleasure to drive. This could be explained by the fact that the system allows to unload the driver of a part of the driving task, but deeper analyses are needed to confirm this hypothesis.

7.4. Events based analysis

Events of interest for road safety are not yet well defined, despite many studies used such a concept. In the EuroFOT project, no video analysis to confirm events automatic detection was planned, and therefore only simple definitions of events were used. Beside the incident definition provided by Benmimoun et al. (2011), automatic triggering was used to detect more simple events such over-speeding, strong jerk, critical time gap, and hard braking (Dingus et al. 2006). Results of the models from section 6.3 are presented at Figure 4 and commented below.

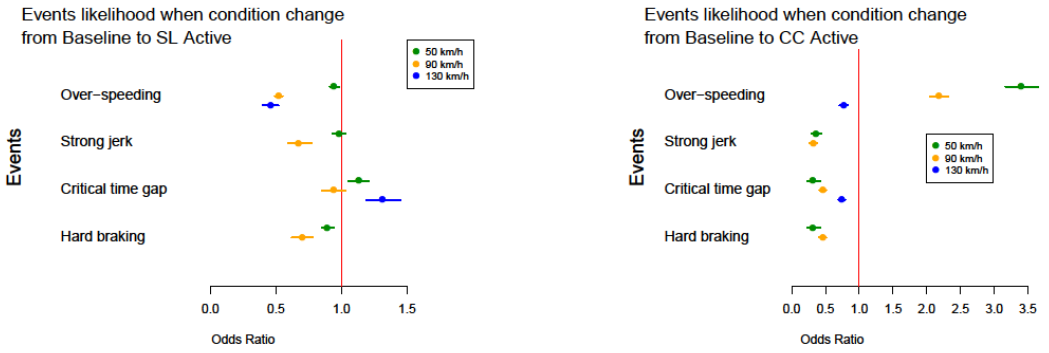

Figure 4: Odds ratio for automatically detected safety critical events when condition change from baseline to SL (a) or CC active (b).

SRS is intended to modify the adopted speed, and so over speeding is the main event to be studied. The effect of the SL on the over speeding events are greater for high speed limits, with a reduction of up to 50% when using the system. An opposite effect is found for the CC, with an increase of the probability of exceeding the speed on most roads (90km/h: OR=3.4; 50km/h: OR=2.18), although it is not the case for motorways (OR=0,77). Looking at strong jerk events, the effects of both SL and CC are positive (i.e. OR<1 except for SL at 50km/h). For CC, the probability of observing this kind of event is approximately reduced by a factor of 3 when using the system.
Critical time gap events likelihood is divided by at least two when CC is active, while the SL tends to increase slightly their frequency. If we consider hard braking occurrences, both system have a positive effect although much less significant for the SL. If we recall that CC is likely to be used when driving conditions are near the optimum (few traffic, no crossings, straight roads etc.), and the opposite for SL, it is therefore not surprising to

obtain more positive effects for the CC than for the SL. EBA is not complete without an incident analysis. The chosen definition comes from Benmimoun et al. (2011), but the OR are not provided by the graphics. The likelihood of the incidents decreased significantly when driving with SL or CC active. But the estimated decrease in incident rate is more important for CC (SL: OR=0,683; CC: OR=0,165). This last effect may be due to driver's choice to use the system when traffic is free flowing instead of the system effect itself.

7.5. Speed & accidents relationships

Results of the speed & accident relationships for accident frequency reduction (AFR) are provided at table 3. These kinds of models do not provide confidence intervals as the parameters are fixed by the data. The global picture is rather negative (AFR>1) due to the general increase of average speed while using SRS. This does not reflect the real impact of the system because it is clear that speed choice is not independent from the traffic conditions.

Table 3: Speed & accident models used for accident frequency reduction computation, according to the system studied and the road characteristics.

Model used & Accident Frequency reduction	**Speed limit**				
Condition	50km/h	70km/h	90km/h	110km/h	130km/h
SL-CC Available	U2 1.21	U2 1.19	Power model 1.03	Power model 1.03	Kloeden Rural 1.11
SL activated	U2 1.47	U2 1.11	Power model 1.02	Power model 1.04	Kloeden Rural 0.98
CC activated	x	x	Power model 1.53	Power model 1.28	Kloeden Rural 1.83

7.6. Scaling-up

Because the CC is used at higher speeds, the average speed when CC is active is higher than average. When SL is active, speeds are average. When SL and CC are off speeds are lower than average. Therefore, as stated earlier, changes in speed behaviour may not be due to the system itself but to driver's choice to use it depending in driving situations. Moreover, The Speed Regulation System (SRS) does not affect mobility behaviour, route choice or choice of road type. Therefore, the traffic efficiency effect of the sub functions CC or SL cannot be determined because usage is not independent from speed. Given these results and the limitations of the investigated models, our conclusion is that a trustworthy up scaling of SL/CC is not feasible; there are too many uncertainties for results of such an up scaling to be viewed as reliable. Different approaches for understanding the impact of SL/CC on accidents need to be further investigated in future work.

7.7. Conclusion on the system effects

These two systems cannot be active at the same time, and the choice to activate it or to change from one system to another largely depends on various parameters of driving conditions that are difficult to control. The previous findings highlight the relationships between systems usage and driving conditions, showing that level of traffic is likely to be an important parameter. Although the congestion level cannot be precisely estimated for the euroFOT data, there are sufficient clues to make the following conclusions. SL is used on all speed limits, with a greater frequency on road with low speed limits or low congestion level, while CC is comfortable to use in conditions when constant speeds can be maintained. People tend to use the CC when the road and traffic conditions allow for fast driving. The increasing speed observed both when SL or CC are active lead to a negative impact on safety according to speed & accident relationships, but this do not take into account the fact that SRS usage is stronger for free flow conditions associated with an high safety level. This kind of behaviour is quite frequent for longitudinal assistance systems: Due to a higher safety level for the use cases of cruise control, drivers tend to drive faster to maintain constant their own acceptable risk level. It is likely that higher risks due to increased average speed may be compensated by the absence of congestion, and the ability of the driver to concentrate on other driving tasks. The low usage rate of 2.69% is an additional indicator that the system is only used under certain driving situations whose driving pattern might be different from the rest of urban driving. Further investigations in a follow up project are needed to improve baseline selection in order to eliminate bias due to driver's system usage related to specific driven conditions.

8. General conclusion and recommendations

Some innovative methods and statistical models were needed during the data analysis process to evaluate the impact on driver behavior of the top speed limiter and cruise control systems, to assess the impact of these systems on driver workload, acceptance and trust, and to estimate the societal benefits of the systems in terms of traffic safety, efficiency and reduction in environmental harm. These include methods for untangling the impact of individual system functions, breaking down and testing research hypotheses, analyzing video and questionnaire data, and scaling up data to estimate societal effects. These approaches were developed and improved during the euroFOT project, and are likely to be used in future field operational tests. The acquired expertise on such probe vehicles data will facilitate IFSTTAR and CEESAR involvement in future FOT projects and increase future scientific cooperation among EuroFOT partners. IFSTTAR already got back to the FOT adventure within the ecoDriver project (FP7). The methods developed to suit EuroFOT needs will be improved in future research works in order to develop a generic way to evaluate embedded longitudinal systems impact on safety. EuroFOT results will be useful to enrich meta data analysis by merging information collected from various research projects. Comparisons between various speed regulation systems impacts will therefore being feasible. Beside these methodological aspects, more technical work is planned in order to improve the detection of important driving situation characteristics. In a near future, IFSTTAR together with CEESAR will improve their baseline random sampling techniques in order to improve the euroFOT results accuracy by correctly selecting comparable data (i.e. comparing CC in use with a road where CC would have been used if available). Such improvements are of primary interest for research purposes and FOT data analysis. All these future works will help improve the understanding of speed & accidents relationship.

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