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Is ESP Effective on French Roads?

Abstract

Electronic Stability Program (ESP) aims to prevent the lateral instability of a vehicle. Linked to the braking and powertrain systems, it prevents the car from running wide on a corner or the rear from sliding out. It also helps the driver control his trajectory, without replacing him, in the case of loss of control where the driver is performing an emergency manoeuvrer (confused and exaggerated steering wheel actions). A new ESP function optimizes ESP action in curves with hard under steering (situations in which the front wheels lose grip and the vehicle slides towards the outside of the curve). A complementary feature prevents the wheels from spinning when pulling away and accelerating. The name given to the ESP system varies according to the vehicle manufacturer, but other terms include: active stability control (ASC), automotive stability management system (ASMS), dynamic stability control (DSC), vehicle dynamic control (VDC), vehicle stability control (VSC) or electronic stability Control (ESC).

This paper proposes an evaluation of the effectiveness of ESP in terms of reduction of injury accidents in France. The method consists of 3 steps:

- The identification, in the French National injury accident census (Gendarmerie Nationale only), of accident-involved cars for which the determination of whether or not the car was fitted with ESP is possible. A sample of 1 356 cars involved in injury accidents occurred in 2000, 2001, 2002 and 2003 was then selected. But we had to restrict the analysis to only 588 Renault Lagunas.
- The identification of accident situations for which we can determine whether or not ESP is pertinent (for example ESP is pertinent for loss of control accidents whilst it is not for cars pulling out of a junction).
- The calculation, via a logistic regression, of the relative risk of being involved in an ESP-pertinent accident for ESP equipped cars versus unequipped cars, divided by the relative risk of being involved in a non ESP-pertinent accident for ESP equipped cars versus unequipped cars. This relative risk is assumed to be the best estimator of ESP effectiveness.

The arguments for such a method, effectiveness indicator and implicit hypothesis are presented and discussed in the paper. Based on a few assumptions, ESP is proved to be highly effective. Currently, the relative risk of being involved in an ESP-pertinent accident for ESP-equipped cars is lower (-44%, although not statistically significant) than for other cars.

Introduction

"I do not seek answers. I seek to understand questions" (Confucius)

Electronic Stability Program (ESP) aims to prevent the lateral instability of a vehicle. Linked to the braking and powertrain systems, it prevents the car from running wide on a corner or the rear from sliding out. It also helps the driver control his trajectory, without replacing him, in the case of loss of control where the driver is performing an emergency manoeuvrer (confused and exaggerated steering wheel actions). A new ESP function optimizes ESP action in curves with hard under steering (situations in which the front wheels lose grip and the vehicle slides towards the outside of the curve). A complementary feature prevents the wheels from spinning when pulling away and accelerating. The name given to the ESP system varies according to the vehicle manufacturer, but other terms include: active stability control (ASC), automotive stability management system (ASMS), dynamic stability control (DSC), vehicle dynamic control (VDC), vehicle stability control (VSC) or electronic stability Control (ESC).

ESP has been a topic of considerable interest since the late 1990s because it concerns a high number of accidents. In 2002, in Europe (15 countries), 1 227 000 injury accidents occurred, 1 670 000 road users were slightly or seriously injured and

37 660 lost their lives (source: CARE database, EU quick indicator, 2004). It is unknown how many of these crashes resulted from loss of control according to its dynamic definition[1], i.e. ESP-pertinent crashes. The CARE database does not record such information. Consequently, the magnitude of loss of control accidents is not accessible from intensive databases and must be estimated from published papers. LANGWIEDER et al. estimated the proportion of skidding accidents in Germany at 25% for injury accidents and 40% for fatal accidents (LANGWIEDER et al., 2004). UNSELT et al. estimated these same proportions at, respectively, 21% and 43% (UNSELT et al., 2004). In the same way, BECKER et al. estimated ESP-pertinent fatal crashes in Germany at 40%, using GIDAS[2] data (BECKER et al., 2004). BAR and PAGE estimated that, in France, these proportions would be around 20% and 40% (BAR et PAGE, 2002). The same is true for Japanese injury crashes (AGA and OKADA, 2003).

If we rely on these consistent estimates, each year in Europe (15 countries), approximately 240 000 injury crashes and 15 000 fatalities result directly or indirectly from loss of control, other factors being of course also relevant in the accident production.

The effectiveness of ESP in preventing these crashes has already been studied in several papers (ZOBEL et al., 2000; SFERCO et al., 2001; LANGWIEDER et al., 2003; AGA and OKADA, 2003; TINGVALL et al, 2003; UNSELT et al., 2004; BECKER et al., 2004). It is not worth reporting in-depth about their findings since each of these papers recalls the previous research results available at the time of publication. The last release even recalls the main issues related to ESP effectiveness (LANGWIEDER et al., 2004). Nevertheless, it is worthwhile mentioning here below some outstanding elements of these studies, and especially their different viewpoints.

[1] Loss of control is often assimilated to road departure. However, roadway departures can be split into two kinds of accidents: guidance problems (the car leaves the road without dynamic problems and is still controllable) and loss of control (the car's transversal acceleration is incompatible with the road grip and the vehicle becomes uncontrollable. Some loss of control crashes are also linked to blocked wheels during braking but these can be dealt with by ABS rather than by ESP).

[2] GIDAS: German In-Depth Accident Study

Expected vs. Observed Effectiveness

Two of these studies addressed the expected effectiveness of ESP prior to the equipment of cars with such devices. The effectiveness is estimated in a two-steps process. First the number of ESP-pertinent injury or fatal crashes (skidding accidents or loss of control) is calculated from available accident databases. Then, a detailed examination of accident cases by experts states whether or not ESP could have had an influence on the sequential development of the crash, taking into account other key elements of the accident. SFERCO et al. came to the conclusion that in 18% of all injury accidents and 34% of all fatal accidents, ESP would have reduced the likelihood of an accident or avoided the accident altogether. LANGWIEDER et al. showed that at least 25% of injury crashes would be ESP-pertinent. The major benefit of ESP is expected in critical situations in bends where the driver attempts several steering wheel actions while skidding or in other situations where the driver does not apply the brakes.

The other studies addressed the observed effectiveness of ESP by comparing the accident rates of ESP-equipped cars versus others or by estimating the proportion of ESP-pertinent accidents for ESP-equipped cars and for other cars. The results depend on the initial assumptions, the availability of data, the effectiveness indicator, the study design, the methodologies used and the statistical techniques. AGA et al. found a 35% reduction in the single car accident rate and a 30% reduction in the head-on collision accident rate for ESP-equipped cars compared to similar unequipped cars in Japan. TINGVALL et al. found a 22% reduction in ESP-pertinent crashes for ESP-equipped cars in Sweden. UNSELT et al. estimated that, in Germany, ESP-equipped cars, when compared to the same DaimlerChrysler cars before systematic ESP equipment, had a 40% reduction in loss of control crashes resulting in a decrease in the overall injury accident risk of 16%. Finally, BECKER et al. calculated a 45% reduction in loss of control injury accidents if all cars were equipped with ESP in Germany (this estimate is even higher if only Volkswagen cars are taken into consideration).

Exposed/Non Exposed Studies vs. Internal Case-Control Studies

Apart from the studies evaluating the expected effectiveness of ESP, the other studies used different methodologies to evaluate the observed effectiveness. The first methodology is a comparison of the accident rates of two car fleets, one composed of ESP-equipped cars and the other of similar unequipped cars. This is known in epidemiology as the exposed/non-exposed quasi-experimental design. Since the kilometrage is usually not available, the denominator of the rate is commonly the number of vehicles sold. The accident rate can be calculated for ESP-pertinent accidents only or for all types of accidents.

The second methodology consists of estimating the proportion of loss of control in crashes involving ESP-equipped and in crashes involving unequipped cars and of comparing these proportions. This is known as the internal Case-Control design. The methodology relies only on crashes data. The cases are ESP-pertinent crashes and the controls are non ESP-pertinent crashes. Statistical techniques used for comparisons may vary considerably between studies.

As a whole, even though most results do not include statistical confidence intervals, all studies conclude that ESP is highly effective and should contribute to considerable reductions in road injuries and fatalities in the coming years as the equipment rate of the European vehicle fleet continues to rise.

This assertion concerns Japanese, German and Swedish accident data because the evaluation studies were performed in these countries. Evidence is missing for other countries. Consequently, this paper proposes an evaluation of the effectiveness of ESP in terms of the reduction of injury accidents in France.

Method and Data

As in the ABS and ESP studies carried out in the past by EVANS (1998), KULLGREN et al. (1994) and TINGVALL et al. (2003), we use a method that refers only to accident data independent of exposure data. The exposed-not exposed method was not possible here since the calculation of accident rates requires either the constitution of ESP-equipped and unequipped car fleets and the recording of their mileage and road accident involvement over several years (which is a costly and inappropriate design since accidents are rare) or a good estimation of the overall fleet currently on the road with and without ESP, for a selection of car makes and models. Furthermore, it would ideally require an estimation of the mileage driven by each fleet. Both information is not available to us.

Our method consists of 3 steps:

- The identification, in the French National injury accident census (Gendarmerie Nationale only), of accident-involved cars for which ESP equipment or non-equipment is known.
- The identification of accident situations for which we can determine whether or not ESP is pertinent (for example ESP is pertinent in loss of control accidents whilst it is not for cars pulling out of a junction).
- The calculation, via a logistic regression, of the relative risk of being involved in an ESP-pertinent accident for ESP-equipped cars versus non-equipped cars, divided by the relative risk of being involved in a non ESP-pertinent accident for ESP-equipped cars versus non-equipped cars. This relative risk is currently assumed to be the best estimator of ESP effectiveness.

First Step

In France, the identification of cars involved in an injury accident is not that easy. Cars are recorded in the national accident census via a code, the so-called CNIT code, which the police copies from the vehicle registration document. Unfortunately, 50% of the codes are not directly identifiable due to errors in the completion of the statistical form. Furthermore, for the remaining 50%, there is no bijection between the code and the determination of whether a car is or is not equipped with a given device. Consequently, instead of identifying whether a car, selected from the accident-involved cars is ESP-equipped, we had to choose a set of cars for which the information was easily accessible and then identify these cars in the accidents according to their make and model, which is easier via the CNIT. This data limitation led us to retain only one make and model: the Renault Laguna. There are two versions of this car. The Laguna 1 was produced in the late 1990s and early

Fig. 1: Renault Laguna 1

Fig. 2: Renault Laguna 2

2000s without ESP (figure 1). In January 2001, Renault launched the Laguna 2, with ESP as standard equipment (figure 2). It was then possible to distinguish the two Lagunas in the accident census using the CNIT (make and model) and the first registration date.[3]

This choice has, of course, certain drawbacks. In particular, the Renault Laguna 2 is a newer car and benefits from other significant improvements such as Emergency Brake Assist, a tire pressure monitoring system and the well-known passive safety improvements, since it was the first car ever to be awarded 5 stars in the EuroNcap consumer tests. Furthermore, the mean age of accident-involved Laguna 2 cars is lower than the mean age of involved Laguna 1 cars for the study period (from 2000 to 2003). These limitations could have generated a bias in the estimation of ESP effectiveness. This issue will be addressed in the third methodological step.

We selected a sample of 1 356 Laguna cars involved in injury accidents occurring in 2000, 2001, 2002 and 2003 in France. These are all the Lagunas we were able to identify in the national accident census. We therefore had to assume that the residual unidentifiable Lagunas, due to errors in typing the car identification code, were randomly distributed among ESP-pertinent and non-pertinent accidents. These accidents are assumed to be very few as we did our utmost to identify all the Lagunas.

Second Step

The method requires the allocation of accidents into ESP-pertinent and non-pertinent accidents. We took this information from the national census by combining several variables such pre-accidental manoeuvre, number of vehicles involved, and type of obstacle. We ended up with a list of 40 accidental situations (table 1). We were not actually interested in the accidents per se, but rather the accident situations, the difference being that the accident situation is linked to a driver-vehicle unit (PAGE et al., 2004). A single vehicle accident has a single situation. In a two-vehicle accident, each driver has a specific accident situation corresponding to the circumstances in which he finds himself. For example in a crossing accident at a junction, the first situation corresponds to the user who pulls out of the intersection after stopping at a stop sign. The second situation corresponds to the driver with right of way who has to cope with a vehicle suddenly crossing his carriageway. This is the reason why we chose to build an accident situation list rather than an accident list.

For each accident situation, we stated whether it was ESP-pertinent and/or braking-pertinent, or neither ESP nor braking pertinent. We made this distribution on the basis of our expertise with respect to in-depth analysis of accidents investigated on-scene.

ESP-pertinent accidents are mainly single car accidents involving loss of control. On the other hand, there are two kinds of non ESP-pertinent accidents: those for which braking is pertinent and

3 Initially, we also kept other vehicles but had to consider the vehicle make and model as a confounder in the analysis. However the ESP variable (Equipped – Not equipped) was perfectly correlated to the model variable. Instead of dropping the variable Model, it was preferable to remove the other vehicles, otherwise the analysis would have been unstable.

those for which it is not. Because Emergency Brake Assist was the other main active safety innovation on Laguna 2 compared to Laguna 1, integrating braking-pertinent accidents in the sample of non ESP-pertinent situations could have generated a bias in the estimation of ESP effectiveness. We finally decided to limit non ESP-pertinent accidents to a subset of accidents for which braking does not apply.

The influence of the Tire Pressure Monitoring system was assumed to be negligible and the influence of passive safety enhancements will be covered in the discussion section.

Type of accident situation	Relevant vehicle/driver function/action
Loss of control or guidance problem	
Single car accident. Loss of control or guidance problem on a straight road outside junction	ESP
Loss of control or guidance problem on a straight road outside junction. Collision with an opponent	ESP + Braking
Single car accident. Loss of control or guidance problem in a bend outside junction	ESP
Loss of control or guidance problem in a bend. Collision with an opponent	ESP + Braking
Single car accident. Loss of control or guidance problem at a junction	ESP
Accident involving a pedestrian	
Car confronted with a Pedestrian walking along the roadway	Braking
Car confronted with a Pedestrian crossing the roadway	Braking
Car confronted with a Pedestrian hidden by an obstacle	Braking
The driver is reversing and hits a pedestrian	
Car-to-vehicle accidents outside junctions	
Opposing vehicle to a vehicle that loses control in a bend	Braking
Opposing vehicle to the vehicle that loses control on a straight road	Braking
Rear-end accident. Striking car	Braking
Rear-end accident. Struck car	
Car changing lane and hit by a car driving in the same direction or in the opposite direction	
Car confronted with an obstacle	Braking
Overtaking car	Braking
Parking or parked car	
Car making a left turn or a right turn	
Car whose occupant opens his door	
Car making a U-turn or car crossing the road	
Car-to-vehicle accidents at junctions	
Car driver at fault in a round-about (left or right turn, insertion, others)	
Car driver not at fault in a round-about (left or right turn, insertion, others)	
Crossroads. Driver at fault going straight	
Crossroads. Driver turning left	
Crossroads. Driver turning right	
Crossroads. Driver going straight ahead confronted with driver going straight in the perpendicular direction	Braking
Crossroads. Driver going straight ahead confronted with driver turning left or right from a perpendicular road	Braking
Same road. Different directions. Car driver not at fault confronted with driver going straight	Braking
Same road. Different directions. Car driver not at fault confronted with driver turning left or right	Braking
Same road. Different directions. Car driver at fault confronted with driver going straight	
Same road. Different directions. Car driver turning right confronted with driver going straight	
Same road. Different directions. Car driver turning left confronted with driver going straight	
Same road. Same directions. Car driver at fault hitting another vehicle going straight	Braking
Same road. Same directions. Car driver not at fault going straight hit by another vehicle	
Same road. Same directions. Car driver hitting another vehicle turning right	Braking
Same road. Same directions. Car driver turning right hit by another vehicle	
Same road. Same directions. Car driver hitting another vehicle turning left	Braking
Same road. Same directions. Car driver turning left hit by another vehicle	
Car driver hitting another vehicle making a U-turn	Braking
Car driver making a U-turn hit by another vehicle	

Tab. 1: Accident situations and ESP-pertinent situations

Not surprisingly, the national accident census is a large database with a low level of detail. Consequently, for certain types of accidents, the allocation to the ESP-pertinent or non ESP-pertinent group is questionable. There might be some classification errors. Some single car accidents are not loss of control accidents but guidance problems. In some cases, the vehicle does not slide broadside but leaves the roadway controllable, from a dynamics point of view. The driver may fall asleep or not react for whatever reason (e.g. inattentive, hypo-vigilant, doing a secondary task, under the influence of alcohol, etc.) and the car goes off the road with no dynamic solicitation. These accidents are unidentifiable in the accident census and are amalgamated with loss of control accidents. We then assumed that the proportion of guidance problems in loss of control situations is negligible.

For pedestrian accidents and some car-to-car accidents (overtaking, car confronted with an obstacle, overtaking car, opponent to a car having lost control), it is assumed that the car driver did not take evasive action and consequently did not lose control through this evasive action. These latter accidents (loss of control due to an evasive action) are mostly classified as loss of control accidents. Some cannot nevertheless be identified as such in our database and are scattered in the other classes. Again, we assumed that they are rare events in these classes (PAGE et al., 2004). Consequently, we supposed that these situations correspond to non ESP-pertinent accidents.

Third Step

Effectiveness is highly dependent on the effectiveness indicator. We must therefore choose it carefully, according to available data. Concretely, in our study, the effectiveness E is estimated by (1).

E = 1-OR = 1 –[(A*D) / (B*C)] (1)

With OR, the odds ratio, A, B, C, D being the numbers of accidents with respect to ESP, as explained in table 2.

	ESP-equipped cars	Non ESP-equipped cars
ESP-pertinent Accidents	A	B
Non ESP-pertinent Accidents	C	D

Tab. 2: Distribution of accidents for the calculation of the odds ratio OR

After several assumptions, and noticeably the assumption that the accident sample is drawn randomly from the accident census, we can show that (e.g. HAUTZINGER, 2003):

$$\mathrm{OR} = \frac{R_{AS}}{R_{A}} = \frac{\dfrac{R_{AS-S}}{R_{AS-NS}}}{\dfrac{R_{ANS-S}}{R_{ANS-NS}}} \tag{2}$$

with:

- $R_{AS\text{-}S}$ is the risk of being involved in an accident where ESP is assumed to be pertinent for an ESP-equipped car.
- $R_{AS\text{-}NS}$ is the risk of being involved in an accident where ESP is assumed to be pertinent for a non ESP-equipped car.
- $R_{ANS\text{-}S}$ is the risk of being involved in an accident where ESP is assumed not to be pertinent for an ESP-equipped car.
- $R_{ANS\text{-}NS}$ is the risk of being involved in an accident where ESP is assumed not to be pertinent for a non ESP-equipped car.

In other words, the odds ratio OR, formulated by (2), has a comprehensible interpretation. Assuming that ESP has no effect at all on accidents in which it is not assumed to be pertinent, ($R_{ANS\text{-}S}/R_{ANS\text{-}NS}$) is assumed to be equal to 1. This commonly supposes no driver adaptation to ESP with for example higher risk taking or higher driving speed. This assumption is confirmed, at least in the short term, by TINGVALL et al., who found no distortion in the proportion of impacting cars for ESP and non-ESP equipped cars in rear-end collisions.

Consequently, the odds ratio measures the relative risk of being involved in an ESP accident for ESP-equipped versus non-equipped cars.

In practice, table 2 only enables the calculation of the crude odds ratio, irrespective of potential confounders. The adjusted odds ratio is then estimated via a logistic regression. It enables confounders such as: Driver age and gender; Vehicle age and Year of accident (these two variables should solve the problem raised above, i.e. the age difference between Laguna 1 and Laguna 2); Pavement status (whether the pavement was dry or wet); Location of accident to be taken into consideration. No reliable information about seat-belt use was available.

Gender	Frequency	%
Female	141	24
Male	447	76
Total	588	100

Tab. 3: Distribution of the cars according to driver gender

Age	Frequency	%
18-24 years old	50	8.5
35-44 years old	259	44.1
45-54 years old	129	21.9
55-64 years old	77	13.1
65 years old and older	73	12.4
Total	588	100

Tab. 4: Distribution of the cars according to driver age

Vehicle age	Frequency	%
Less than 1 year old	114	19.4
1 to 2 years old	91	15.5
2 to 3 years old	77	13.1
3 to 4 years old	91	15.5
4 to 5 years old	98	16.7
Over 5 years old	117	19.8
Total	588	100

Tab. 5: Distribution of the cars according to car age

Pavement State	Frequency	%
Dry	477	81
Wet	111	19
Total	588	100

Tab. 6: Distribution of the cars according to the pavement state at the accident

Location	Frequency	%
Inside urban area	176	29.9
National Road	81	13.8
Secondary network	267	45.4
Others	64	10.9
Total	588	100

Tab. 7: Distribution of the cars according to the accident location

Year of accident	Frequency	%
2000	150	25.5
2001	182	30.9
2002	171	29.1
2003	85	14.5
Total	588	100

Tab. 8: Distribution of the cars according to year of accident occurrence

	ESP as standard equipment	No ESP	Total
ESP-pertinent accident situations	22	177	199
Non ESP-pertinent accident situations	71	318	389
Total	93	495	588

Tab. 9: Distribution of the cars according to their involvement in ESP-pertinent or non-pertinent accident situations

Results

Simple Statistics

The limitation of the accident situations to those related specifically to ESP and those related to neither ESP nor braking dramatically lowered the number of situations to be considered. We finally retained 588 out of the initial 1356 cars. Unfortunately, the small sample size can generate unstable coefficients in logistic regression and/or large confidence interval of the odds ratio. We will come back to this issue in the discussion section.

Tables 3 to 8 show the distributions of each confounder. For most of them, the distribution does not show cells sufficiently unbalanced to disturb the analysis.

Crude Odds Ratio

Table 9 displays the repartition of accident situations according to ESP equipment and pertinence.

From this table, we can calculate the crude odds ratio, OR = (22*318) / (71*177) = 0.56. We can also calculate the confidence interval of the odds ratio[4] [0.46;1.29]. The effectiveness is then calculated by (1): 1-0.56 = 44%. The risk of being involved in an ESP-pertinent accident for ESP-equipped cars is 44% lower than the same risk for non-equipped cars. However, as expected, this result is not statistically significant because of the small sample size.

This first result has to be validated by a more sophisticated analysis taking possible confounders into consideration. This was done using logistic regression (table 10).

Logistic Regression

Logistic regression enables the estimation of the adjusted odds ratio and its confidence limits. The crude odds ratio is then adjusted by the values of the explanatory variables. The variable of greatest interest is, needless to say, the presence of ESP in the car. The other variables are taken into consideration as confounders (Driver Age and Gender, Pavement State, Accident Location) and

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4 For a presentation of the computation of the confidence interval of the odds ratio, refer for example to BOUYER et al. (1995) or PAGE (1998).

also to counter the potential bias due to the limitation of data. For example, the bias selection due to the restriction of cars to Lagunas of different generations is countered by the integration of vehicle age and year of accident in the regression model.

It should be remembered that logistic regression requires the fixing of a reference point for each variable (i.e. one of the values of the variable), which is then used to explain the results across the entire variable. For example, the variable Driver Age is the explanatory variable at a reference point of 25-44 years of age. Thus the relative risk of accident involvement for drivers aged 18-24 is greater than for 25-44 year-olds (odds ratio of 4.2) and decreases for 45-54 year-olds (odds ratio between 0.75 according to the model). Overall, for this explanatory variable, we can say that the relative risk of accident involvement decreases with age. The reference points for each explanatory dimension are highlighted in italics in table 10.

Logistic Model (ESP-pertinent accident situations versus neither ESP nor Braking-pertinent accident situations)			
Number of observations: 588 ESP-pertinent cases : 199 / Non ESP-pertinent cases : 389 AIC : 651 SC : 734 -2 Log L : 613			
	Odds ratio	Min.	Max.
ESP			
ESP fitted in the car as standard equipment	0.57	0.25	1.30
ESP not fitted in the car	-	-	-
Driver Age			
18-24 years old	4.21	2.06	8.64
25-44 years old	-	-	-
45-54 years old	0.75	0.45	1.25
55-64 years old	0.46	0.23	0.89
65 years old and older	0.60	0.32	1.15
Gender			
Female	0.99	0.62	1.59
Male	-	-	-
Vehicle Age			
Less than 1 year old	0.74	0.3	1.81
1 to 2 years old	1.6	0.77	3.42
2 to 3 years old	1.2	0.58	2.49
3 to 4 years old	0.6	0.31	1.30
4 to 5 years old	1.10	0.55	1.30
More than 5 years old	-	-	-
State of the pavement			
Wet	2.67	1.6	4.29
Dry	-	-	-
Location			
National Roads	5.85	2.88	11.89
Secondary network	6.36	3.57	11.32
Inside urban areas	-	-	-
Others	13.8	6.5	29.23
Year of the accident			
2000	-	-	-
2001	0.83	0.49	1.40
2002	1.02	0.57	1.88
2003	0.48	0.21	1.09
Percent of concordant Pairs : 78%/Somer's D = 0.57/ Gamma = 0.57/ Tau-a = 0.25 / c = 0.78			

Tab. 10: Results of the logistic regression

The adjusted odds ratio correspondent to ESP, 0.57 and its confidence interval [0.25;1.30], are not very different from the crude odds ratio. Based on the crude and on the adjusted odds ratio, we can then confirm that ESP is apparently very effective (43% reduction in the risk of being involved in an ESP-pertinent accident for ESP-equipped cars versus non-equipped cars). However, this estimation is not statistically significant and holds only for our selection of cars: the Renault Laguna.

Other results are consistent with the literature. Youngsters have a higher risk of being involved in loss of control accidents. Females have a similar risk of loss of control than males; wet pavement is associated with a higher risk of loss of control compared to dry roads. National and secondary and tertiary road networks are associated with a higher risk of loss of control compared to urban areas. Finally, accidents occurring in 2003 are also associated with less loss of control. This can be explained by the incredible increase in road safety on French roads starting in the later months of 2002, partially due to lesser driving speeds. We will talk about this issue further in the discussion section.

Discussion

All studies available so far conclude that ESP is highly effective and should contribute to considerable reductions in road injuries and fatalities on European roads in the coming years as ESP equipment rate is rapidly growing (e.g. more than 50% of newly registered cars in Germany, up to 30% in France). As there was no evidence of such effectiveness in France, this paper addresses this effectiveness issue in France.

To estimate ESP effectiveness, we used a method that only refers to accident data irrespective of exposure data. The method consisted of 3 steps. First we selected makes and models of cars involved in injury accidents in France, from year 2000 to year 2003, for which the determination of whether or not the car is fitted with ESP is possible.

It led us to conserve only Renault Laguna cars. Laguna 1, released before January 2001, was not equipped with ESP whereas Laguna 2, released after January 2001, was ESP-equipped.

Then we identified 40 various accident situations and also split these accident situations into four groups according to whether they were ESP-pertinent, Braking-pertinent, ESP and Braking-pertinent or neither ESP nor Braking-pertinent. The identification of braking as a potential avoidance or injury mitigation manoeuvre is necessary because the Laguna 2 is also equipped with emergency brake assist that could also be effective and act in combination with ESP. As we wished to measure only the effectiveness of ESP, we had to withdraw the braking-pertinent accident situations from the analysis. Finally, we ended up with a sample of 588 accident situations, 199 being ESP-pertinent and 389 being non ESP-pertinent.

The estimation of the effectiveness of ESP was carried out using the adjusted odds ratio, which can be interpreted as the relative risk of being involved in an ESP-pertinent accident for a Laguna 2 fitted with ESP versus Laguna 1 non fitted with ESP, divided by the relative risk of being involved in a non ESP-pertinent accident for a Laguna 2 fitted with ESP versus a Laguna 1 not fitted with ESP. This relative risk is assumed to be the best estimator of the ESP effectiveness.

A series of implicit or explicit assumptions were made during the course of the evaluation and a few difficulties also arose from the data and method.

- The effectiveness indicator, i.e. the odds ratio, supposes that there is no driver adaptation to ESP, and especially that the non ESP-pertinent accidents are not affected by the presence of ESP. This is not a major assumption as ESP is relatively badly understood (according to Bosch, only 30% of drivers know what ESP is) and should not lead to risk compensation, at least by now. However, the method itself is based on this assumption and therefore it should not be ignored.
- The effectiveness depends heavily on the breakdown of accident situations into ESP-pertinent and non-pertinent situations. Apart from classifcation errors due to the use of imprecise national accident census, we took care to withdraw accident situations that could be pertinent to another safety system such as emergency brake assist. On the other hand, this resulted in a small accident situations sample that reduced the stability and the accuracy of the effectiveness estimation (large confidence interval). A larger sample should be sought. In time, the number of identifiable cars in the national census will grow and we will be able to update our result.
- The effectiveness holds only for one make and model of the M2 segment: the Renault Laguna. Other cars were withdrawn from the analysis because make and model weres perfectly correlated with ESP equipment. This does not mean that the effectiveness holds for other cars and other segments.

We should seek for ways to integrate more cars into the sample while taking into consideration the differences in car makes and models. Once again, the increase in sample size and the variety of identifiable cars could be of great help in the future.

On the other hand, we took care in the logistic regression to consider vehicle age and the year of the accident which counter the fact that the compared cars are the same vehicle from different generations for which ESP comes as a new device at a certain point of time.

- That raises another crucial issue. The cars that we have compared, although identical in make and model, are completely different thanks to the dramatic improvements on the Laguna 2 concerning active and passive safety. The presence of tire pressure monitoring is not considered as having an enormous influence on accident involvement and the presence of the emergency brake assist on Laguna 2 only has been dealt with via the accident types. But the problem of passive safety improvements still remains. It is natural (and proven) to consider that the likelihood of sustaining injuries in Laguna 2 is dramatically reduced compared to Laguna 1. The only problem that arises is to state whether or not this reduction is identical for ESP-pertinent and non-pertinent accidents. If it is the case, no bias is generated in the analysis. We have not tested this hypothesis so far. We implicitly considered that it is true. Further work should address this important matter.

Similarly, ESP systems fitted in cars are not identical. ESP configuration depends on the suppliers as well as the instructions given to suppliers by the car manufacturers. It is impossible to state from our analysis which ESP system provides better results.

- We evaluated the short-term effect of ESP. The long-term effect might be different as drivers increase their awareness of ESP benefits. This could generate a driver adaptation and then a likely reduction of the ESP effect. Once again, an update of the study within a few years would eventually highlight this issue.
- TINGVALL et al. studied the effect of ESP for different car sizes and different weather conditions. As our sample size is small, we have not been able to do so. We highlighted an overall effect while being unable to attribute this effect to certain types of cars or certain accident situations. We have recently launched a research program to investigate in-depth accidents involving newer cars equipped with as many safety systems as possible in order to add qualitative information to the statistical analysis. In the coming months, we should be able to complete this overall picture of the effect of ESP with accurate in-depth analysis of a selection of accident cases and evaluate what the accident mechanisms are behind this effectiveness. Simulator on track experiments will also provide us with some insights into the influence of ESP.
- The analysis focused on injury accidents only (injury accidents and fatal accidents combined). As mentioned in the introduction, loss of control accidents account for approximately 25% of injury accidents and 40% of fatal accidents in Germany and in France. If we assume that the estimated effectiveness is similar for injury and fatal accidents, there should be a greater overall benefit for fatalities than for injuries. If 100% of the fleet was equipped with ESP, we would expect a 16% reduction in overall fatalities and a 10% reduction in overall injuries.

Now we must consider whether the spectacular evolution of road traffic safety in France since June 2002 can be attributed to ESP. For the year 2003, the figures show a 20.3% decrease in injury accidents, a 20.9% decrease in road deaths and a 15.9% decrease in road accident injuries compared to year 2002.

This situation is exceptional. Such a decrease has only been seen twice before in France; in 1974, after the generalized introduction of speed limits and compulsory seat-belt use and, to a lesser extent, in 1978, with the introduction of a law allowing preventive alcohol testing of car drivers. The European countries for which statistics are available do not show a similar evolution in 2003. The situation is somewhat contrasted (-6% in Germany and +6% in Holland for example for the first 7 months of the year, but -19% in Finland and -10% in Sweden for the first 8 and 5 months of the year respectively). In the absence of comprehensive models to explain the road safety situation in France in the short and medium terms, road safety watchdogs in France impute this reduction to 3 main groups of factors:

- The declaration by the head of state on the 14th July 2002 that road safety was now a national issue.
- Unprecedented media coverage of road safety following this declaration and reinforced in September 2002 with the organization of a national road safety congress.
- The preparation of the 12th June 2003 road safety law, which is predominantly repressive (harsher fines and prison sentences for serious infractions, probative driving license for young drivers, etc.).

These elements contributed to a short-term increase in road safety awareness, an increase in traffic policing (+15% for alcohol testing and more speed controls in 2003), a dramatic increase in seat-belt use (seat-belt use by car front occupants is now 97% in rural areas and 90% in urban areas compared to 95% and 80% respectively in 2002), and finally to a reduction of driving speeds (exceeding speed limits by 10km/h decreased from 35% to 25%) and alcohol consumption when driving.

Experts are nevertheless curious as to the long-term effects of this combination of positive factors. The recent arrival on the roadside and in everyday conversation of automatic speed cameras, the visible element of the automatic control-sanction chain will undoubtedly help to maintain this behavioral moderation and hence produce long-term effects.

Even though it is generally acknowledged that infrastructure and vehicle actions have not produced such dramatic short term effects, it is obvious that they have a long-term structural effect which complements and encourages short-term behavioral actions. In particular, it is right to say that ESP is very efficient in reducing loss of control accidents. Our study showed that ESP could effectively reduce these accidents by 43%. As earlier stated, if 100% of vehicles were equipped with such a device, the observed effectiveness would be a 16% reduction in fatalities. But the equipment rate is much lower than 10% in the current fleets, considering all car ages. ESP is thus assumed to have saved, at most, just a few percent of the fatalities, considerably less than the 20% observed in France in 2003. ESP is consequently definitively not the cause of the increase of safety in France over the last two years. Most probably, changes in driver behavior and, as a long-term effect, the progress in on-board protection are the main causes of such a success.

Nevertheless, as ESP efficiency is very high and as the equipment rate is growing rapidly, ESP will definitely be a major contribution to further reductions in the road toll. It has already proven effectiveness and should be considered as a major safety device in the coming years, especially in combination with passive safety devices, for example pretensioners, load limiters and airbags, which have also proven a very high efficiency (-80% of fatal thoracic injuries) and with other active safety devices.

From a purely research perspective, our ambition is now to go beyond the evaluation of one system independently of the others, to overcome the methodological difficulties and assess the effectiveness of passive and active safety systems acting in combination with one another.

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