POTENTIAL EFFECTIVENESS OF ELECTRONIC STABILITY PROGRAMS (ESP) - WHAT EUROPEAN FIELD STUDIES TELL US

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ABSTRACT

ESP (Electronic Stability Programme) systems enable the stability of a car to be maintained during critical manoeuvres and to correct potential understeering or oversteering. As a result, ESP could help improve car safety by avoiding loss of vehicle control accidents as well as by reducing their severity or consequences.

This paper describes an evaluation of the potential effectiveness of ESP if it was installed more widely. It is based on data from the European Accident Causation Survey (or "EACS") which contains information about 1,674 accidents in 5 European countries.

Analysis of the EACS data shows that in approximately 18% of all injury accidents and in 34% of fatal accidents, ESP would have a certain influence (either reducing the likelihood of an accident or avoiding the accident altogether). Where accident causation was identified as "loss of vehicle control", ESP would have a certain benefit in 42% of cases with injury outcome and in 67% of the fatal crashes.

INTRODUCTION

Electronic Stability Program

The Electronic Stability Programme (or "ESP") is an on–board car safety system which enables the stability of a car to be maintained during manoeuvring and to correct potential understeering or oversteering.

Various authors have described the background theory and development history of ESP[1,2,3,4,5].

ESP uses sensors to determine the course the driver desires and the actual course the vehicle is taking. This is shown schematically in Figure 1.

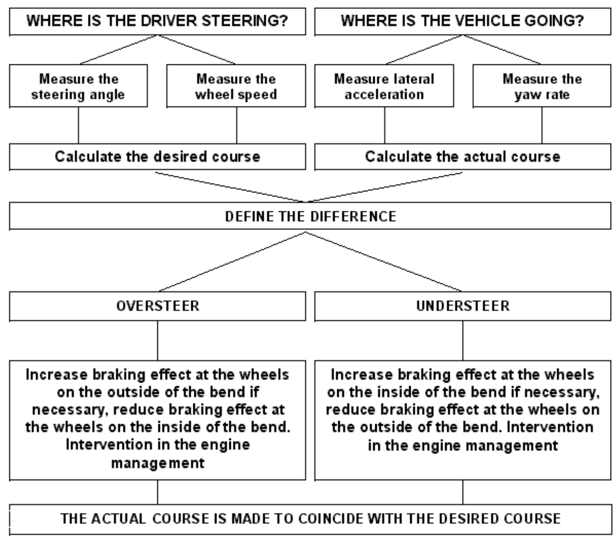

Figure 1. Principle of ESP operation

When these are different, the system acts on the vehicle's braking and engine management system to correct the actual course and make it coincide with the driver's desired course.

The principle of ESP in shown for understeer situations in Figure 2 and for oversteer situations in Figure 3.

ESP is becoming more widely available on cars in the European fleet. It is a natural extension to the increasing application of electronic sensors and controls on vehicles and it takes advantage of components from existing systems such as anti-lock braking, traction control and engine management.

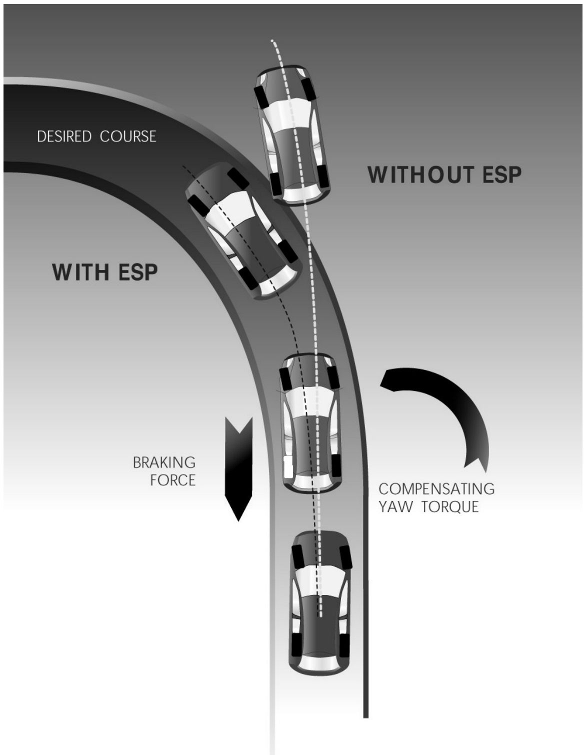

Figure 2. Action of ESP in understeer situations

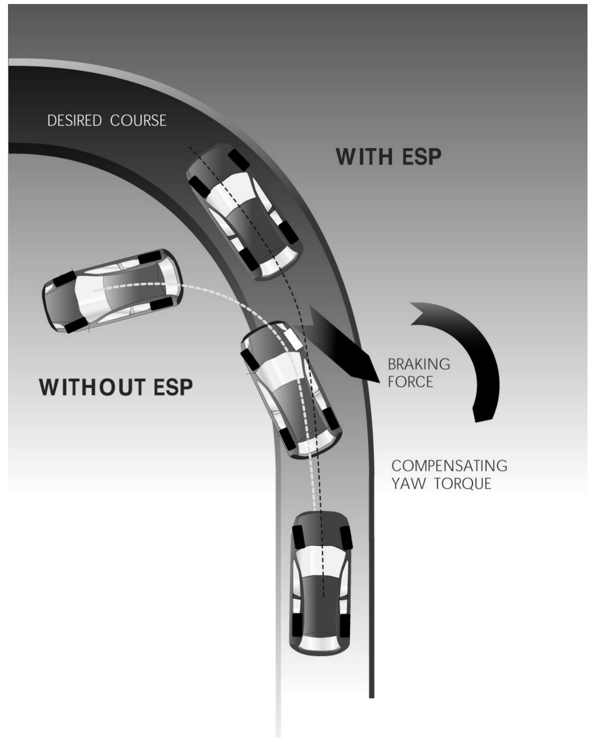

Figure 3. Action of ESP in oversteer situations

The European Accident Causation Survey

The European Accident Causation Survey (EACS) is an European research program aimed at acquiring broader knowledge of road accident causes. It was launched by the European Automobile Manufacturers Association (ACEA) and the European Commission in 1996.

The study has built on existing work in various countries investigating primary road safety using in-depth prospective and on-the-spot accident investigations[6,7].

The set up and methodology of EACS were described in detail by Chenisbest et al[8] at the 16th ESV Conference in 1998. At this time, Phase 1 of the study, consisting of 1,000 cases, had been completed and an initial database established.

Since then, the second phase of the study has been completed and the combined database now includes in-depth information about 1,674 accidents occurring in 5 European countries from 1995 to 1999[9].

Before EACS was established, most of the in-depth investigations of car accidents were not able to provide answers on active safety questions since they were focussed on passive safety considerations.

EACS was started at a time when it was assumed that, because such great improvements in passive safety have been achieved (e.g. improved structures, advanced restraint systems, EU Directives on Frontal and Side Impact), there would be a need for new initiatives in crash avoidance.

Expected outcomes of EACS were the identification of critical situations, the analysis of counter-measures effectiveness, some help in designing new technical devices, the understanding of accident genesis, the analysis of malfunction of the "driver/road/vehicle" loop, the definition of typical accident scenarios, the ranking of priorities for crash avoidance and the definition of a detailed accident collection form and methodology[9].

Within EACS, several accident investigation teams are responsible for collecting and coding a wide range of information about the road accidents that they are investigating and putting the data into a single European database.

The study is based on an in-depth questionnaire prepared in advance by accidentology experts. This prospective data collection methodology provides more complete data than a retrospective one. It also makes it possible to obtain detailed information on the influence of human and road/environmental factors and traffic conditions on the occurrence of specific accidents and injuries.

The first two phases of EACS were achieved with the active participation of eight institutes or companies which were already carrying out such accident investigations before EACS started. They agreed to allow EACS to take advantage of their methodology and data. The institutes were:

- **Finland**:
  - The University of OULU in co-operation with the Finnish Motor Insurer's Centre (VALT)
  - The University of Turku
- **France**:
  - The National Institute for Transport and Safety Research (INRETS)
  - The European Centre for Safety Studies and Risk Analysis (CEESAR)
- **Germany**:
  - DEKRA
  - The Accident Research Unit of the Medical University of Hannover
- **Italy**:
  - ELASIS
- **Spain**:
  - INSIA

Starting with Phase III of EACS, a new team (TNO in The Netherlands) will be introduced.

Up to June 2000, 1,674 accidents cases had been investigated and information about these crashes were collected and coded in the so-called DAMAGE database (a Databank to analyse Accident Mechanism and Accident Genesis in Europe). All types of accidents involving injuries with at least one passenger car involved are taken into consideration.

The authors believe that this is the first published paper to make use of EACS data.

Analysis Methodology

The main purpose of the current study is to estimate the potential benefits of ESP in car accidents in Europe, measured by the number of accidents in which it is judged that the presence of ESP would have influenced the outcome.

This approach used in this study is the first step of a proposed three stage assessment. The first stage, covered in this paper, is to identify the proportion of accidents in which the proposed countermeasure could influence the outcome (this is referred to as the "opportunity".) In the second stage, the effectiveness (or "capability") of the available technology in influencing the outcome would to be established. Finally, in the third stage, the effect on driver behaviour of having the countermeasure fitted would need to be determined.

As it is still impossible to undertake a fleet study (ie a comparison of accidents rates between two fleets of similar cars, one quipped with ESP and the other one not equipped) because there are too few cars equipped with ESP so far, it was proposed to estimate a *potential* effectiveness of ESP, analysing a large sample of accidents and relying on experts' opinion deciding, case by case, whether ESP would have potentially influenced the process of the accident.

This work was carried out by using the EACS database that includes four different types of variable:

- Descriptive variables that give an objective value, e.g. *the age of the car occupant*.
- Variables that need the investigator's expertise, e.g. *the use of seat belt*.
- Variables that need an occupant statement, e.g. *the declared driving speed before the accident situation*.
- Analytic variables that need an evaluation of the investigator, e.g. *Could an accident avoiding system have helped a user to avoid the accident*?

Specific attention was focused in this study on the fourth group of variables. All the investigators collecting data for EACS and analysing the accident cases were asked to use their experience, expertise, knowledge of the accident (and especially its dynamic reconstruction) and judgement to determine how the outcome of the accident would have changed if ESP had been available.

The experts were asked to record their judgement in the database as follows[10]:

1 ESP would have definitely not influenced the accident
2 ESP would have maybe influenced the accident
3 ESP would have probably influenced the accident
4 ESP would have definitely influenced the accident
5 ESP would have definitely avoided the accident

Consequently, the analysis carried out for the current study mostly relies on accident reconstruction and experts' opinion. Categories 3, 4 and 5 above were regarded as being those where there was high confidence that the accident outcome would have been influenced by the presence of ESP.

It is worthwhile mentioning that this way of estimating a potential benefit does rely on subjective interpretations of the accident and does not take into account any risk compensation that could occur with the driver's awareness of driving a car equipped with safety features. Therefore, the effectiveness estimates calculated should be viewed as an upper limit on the likely effectiveness.

Before analysing the EACS data, a limited analysis of the official national accident statistics from a number of European countries was carried out to give an indication of the magnitude of loss of control accidents in the general accident population.

Finally, an example case from EACS has been selected to illustrate an accident situation in which it is believed that ESP would have made a difference and to show the level of judgement used to determine the likely influence of ESP.

RESULTS

Official Accident Statistics

Official accident statistics from a number of countries suggest a large benefit from the application of ESP. In particular, a significant number of fatal accidents are reported as involving loss of vehicle control or skidding before impact or involve only a single vehicle.

In Germany, 42% of fatalities to car occupants occur in driving accidents (i.e. loss of vehicle control). 46% of German accidents involving fatal car occupants are single vehicle accidents[11].

In the UK, 30% of cars involved in single vehicle accidents skidded before the crash and also in 43% of the single vehicle accidents, the driver lost control of the vehicle[12].

French data show that at least 35% of fatal accidents happened after a loss of vehicle control, occurring either as the manoeuvre at the beginning of the accident sequence or a consequence of a inappropriate manoeuvre (i.e. braking and/or steering)[13].

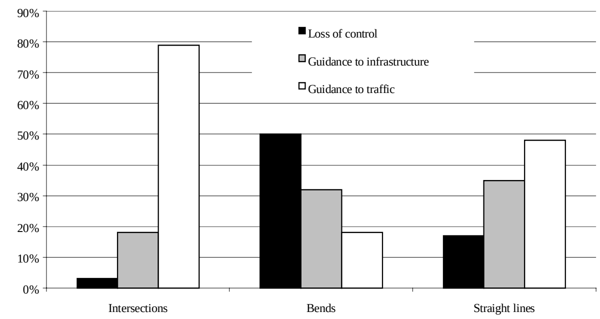

Figure 4. Distribution of accidents types by road geometry

Figure 4 shows the distribution of French injury accident types with a breakdown by road geometry. "Loss of control" is recorded whenever there is objective evidence of car sliding laterally or longitudinally confirmed by drivers' interviews and the reconstruction. "Guidance to infrastructure" corresponds to a lane departure, bad positioning of the vehicle in its lane or a problem in obeying the traffic signals. "Guidance to traffic" refers to a bad entry into the traffic flow or bad positioning in the traffic. The data show that in 50% of injury accidents occurring in bends and in about 18% of injury accidents in straight lines, the driver loses control of his vehicle, either laterally (i.e. the vehicle slides sideways) or longitudinally (e.g. the driver brakes too hard and the vehicle slides forward with locked wheels).

EACS Data

Initial analysis of all accidents in the EACS database suggests that ESP could have a probable or definite influence in about 34% of fatal accidents and 18% of injury accidents (see Figure 5).

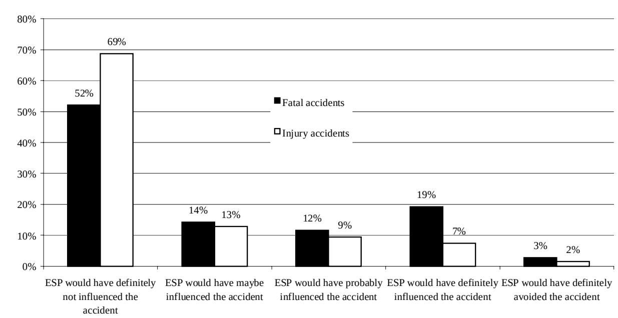

Figure 5. Potential for ESP estimated from EACS data for all accidents

When only accidents involving loss of control are considered (approximately 40% of all EACS accident cases), the EACS data suggests that ESP could have a probable or definite influence in about 67% of fatal accidents and 42% of the corresponding injury accidents (see Figure 6).

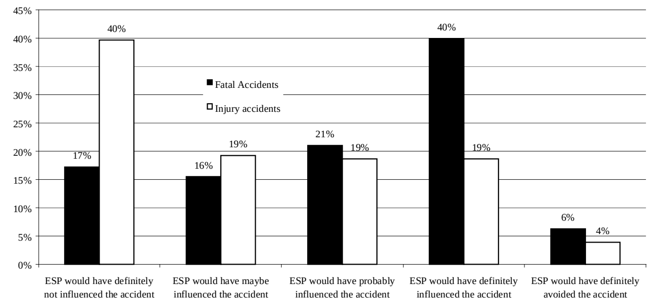

Figure 6. Potential for ESP estimated from EACS data for all accidents involving loss of control

ESP seems to have a high potential benefit, particularly in the case of accidents involving loss of control, but it should also be stressed that the expert EACS investigators do not often choose category 5 (i.e. that ESP would definitely have avoided the accident) but more frequently select one of the lower categories which suggest the probability that ESP would have had an influence on the accident by either avoiding it or by a reduction in accident severity (see Figure 6).

More detailed analysis shows that accidents involving loss of control have specific patterns. Table 1 shows some of these patterns and the breakdown by accident severity also stresses some differences between injury accidents and fatal accidents.

	Loss of Control Injury Accidents	**Loss of Control Fatal Accidents**
Weather		
Rain	13% (10%)	14% (9%)
Number of lanes		
One lane	80% (66%)	86% (63%)
Two lanes	13% (23%)	9% (20%)
(in each direction)		
Road shoulder		
Grass shoulder	27% (17%)	36% (29%)
Surfaced shoulder	24% (26%)	18% (18%)
Driving in a …		
Straight line	47% (30%)	39% (38%)
Curve	40% (8%)	50% (8%)
Evasive action		
Braked	17% (30%)	12% (18%)
No reaction	17% (26%)	34% (14%)
Turned (left or right)	14% (6%)	6% (4%)
Braked then turned	7% (7%)	5% (5%)
Combination	5% (1%)	2% (1%)
Accident causation		
Excessive speed	18% (15%)	18% (18%)
Inappropriate speed	17% (9%)	15% (13%)
Wrong lane travel	5% (3%)	2% (1%)
Overfatigue	4% (1%)	5% (1%)

Vehicles in fatal accidents: 1 093
Vehicles in injury accidents: 1 851
Vehicles in loss of control fatal accidents: 389
Vehicles in loss of control injury accidents: 460

Note: The figures in brackets refer to other types of accidents.

Table 1. Distribution of cars in loss of control accidents according to environmental conditions, driver actions and accident causation factors.

Accidents involving loss of control generally occur more often than other types of accidents on roads with only one lane in each direction, in the rain, when the shoulder is grass, on curves and on straight lines. There seem to be few loss of control accidents at junctions. Inappropriate or excessive speed is frequently identified as a causation factor in both loss of control and other accidents.

It is worthwhile mentioning that ESP is not only relevant in curves when the driver oversteers, understeers or locks the wheels and continues going forward instead of cornering to the right or left but also in straight lines whenever the drivers leave the lane and correct their path by inappropriate steering wheel action(s).

Considering evasive actions performed by the driver, we notice as previous studies that one driver out of four involved in an injury accident does not react at all. In loss of control accidents, this lack of reaction is less common and this should be borne in mind when developing ESP (i.e. remember that the driver often tries to recover the situation by braking, steering or a combination).

	Loss of Control Injury Accidents	Loss of Control Fatal Accidents
Weather		
Rain	40%	91%*
Number of lanes		
One lane	47%	86%
Two lanes (in each direction)	27%	9%
Shoulder		
Grass shoulder	41%	36%
Surfaced shoulder	50%	18%
Driving in a …		
Straight line	36%	39%
Curve	55%	50%
Evasive action		
Braked	38%	70%
No reaction	41%	26%*
Turned (left or right)	40%	45%
Braked then turned	24%	60%*
Combination	45%	50%*
Accident causation		
Excessive speed	70%	87%
Inappropriate speed	45%	82%
Wrong lane travel	40%	52%*
Overfatigue	5%	46%*

*Note: In these cases the sample size is very small (n<56)

Table 2. Percentage of cars in loss of control accidents where ESP would have a probable or definite influence.

The data in Table 2 shows that ESP is most likely to be effective in accidents occurring on roads with one lane in each direction, in the rain and at high speed. It also appears that ESP would be more effective in fatal accidents.

A Case Example

The following example case from the EACS database has been selected to illustrate an accident situation in which it was judged that ESP would have made a difference and the level of judgement used to determine the likely influence of ESP.

The accident occurred in France in 1999 on a local road. The weather was overcast and the road surface was dry. The accident happened between a right hand and a left hand bend on a deformed road surface. Mr L, a 30 year old manager, was driving to an appointment. He was late and driving over the speed limit (about 120 km/h whereas the speed limit is 90).

As he was coming out of a right hand bend, he lost control of the car which then headed straight towards the left hand verge. He braked hard but could not avoid leaving the road and hitting a wall before turning though 180° and stopping. (See Figures 7 and 8).

Mr L was slightly injured. A breathalyser test result was negative.

In this case, Mr. L. was perfectly aware that he was losing control. He tried to brake and to steer but without success. In this particular case, the expert investigator judged that, despite the high speed, ESP could have certainly have influenced the accident because the driver got himself in a situation for which ESP has typically been developed: loss of control in a bend. ESP could have kept the vehicle in its lane. The mean curve radius is approximately 400 meters and should present no particular difficulty.

Figure 7. Photographs of the example accident case

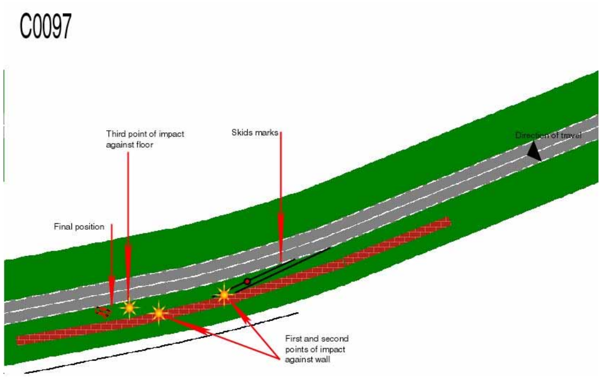

Figure 8. Reconstruction sketch from the example case.

DISCUSSION

Until data from EACS became available, very few recent analysis of the causes of accidents or the effectiveness of primary safety features by using real world crash data had been published.

Sabey[14] examined the causation factors in over 2000 accidents in the UK in the 1970s. She classified the causes into three groups: the road environment, the road user and the vehicle. Most of the accidents only involved one causal factor but about 30% involve two or all three of the factors. Her analysis is shown in Figure 9.

It indicates that road users (e.g. driver or pedestrian) were at least partially at fault in over 94% of accidents and the sole contributor in 65% of accidents. In contrast, the vehicle was only a causal factor in 8½% of accidents. In these cases, the vehicle factors included both design issues and the condition of the vehicle.

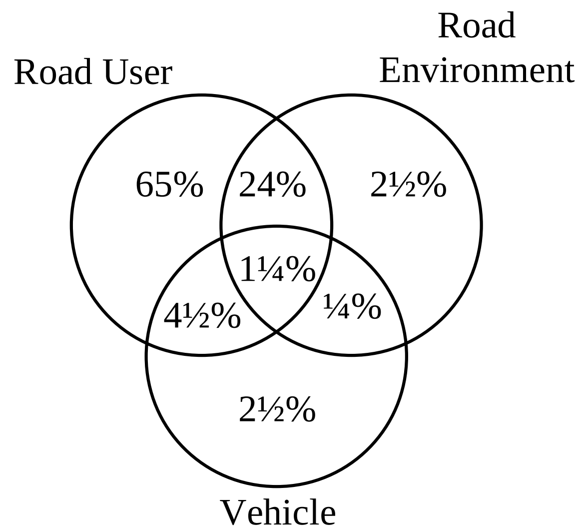

Figure 9. Contributory factors in the causation of road accidents

Treat[15] carried out a similar study of US accidents and reported that the road user was a contributory factor in 71% of accidents and the vehicle in 4.5%.

Thomas[16] reports from in-depth accident studies in France that in approximately 50% of injury accidents, the driver fails to perceive the conflict situation that he has to cope with (i.e. he does not see the other vehicle, he does not correctly perceive the curve radius or he sees an obstacle too late). In cases when he does correctly perceive the situation, he may not interpret the situation correctly, may decide incorrectly what he has to do or may even decide correctly but fail in performing the necessary action correctly. In such conditions, it was felt appropriate to assist the driver or to correct the effect of his failure.

Despite the low involvement of vehicle design factors in accident causation, much attention has been given to improving primary safety performance of vehicles further. In most cases, these are addressing accident situations where the driver is identified as the major causation factor but where vehicle engineering actions can help the driver avoid reaching critical conditions, cope with them better or be informed of potentially risky situations in advance.

Typical vehicle design measures to improve primary safety have included the introduction of anti-lock braking systems, improved vehicle handling and control (such as ESP) and advanced lighting and signalling systems[17].

It has been suggested by OECD[18] that primary safety design features may not be introduced primarily for reasons of safety but as a “by-product” of improvements in vehicle performance. For instance, anti-lock braking systems and advanced tyres are advertised by manufacturers as aids to high speed driving although they also offer safety benefits.

Unlike analysis of in-depth accident data for consideration of secondary safety issues, data analysis for accident causation and assessment of potential counter measures is not yet well developed or understood. If countermeasures for secondary safety are introduced, it is a relatively straightforward task to look at crashes of similar severity involving vehicles before and after the feature was introduced and look for reductions in injury risk. The same assessment opportunities do not exist for active safety development. There is no established data collection procedures for identifying the "good news" (i.e. the high risk situations which did not result in accidents because of the effectiveness of active safety features). It is therefore necessary to adopt different approaches when predicting the likely effectiveness of active safety developments.

The approach used in this study is the first step of a proposed three stage assessment. The first stage has identified the proportion of accidents in which ESP could influence the outcome (the "opportunity".) In the second stage, the effectiveness (or "capability") of the available technology in influencing the outcome would need to be established and further experience of the performance of ESP systems in a wide range of driving situations is needed before this could be achieved with any confidence. Finally, in the third stage, the effect on driver behaviour of having ESP fitted would need to be determined.

If drivers continue to drive in the same manner and accept the safety benefits offered by ESP, then much of the potential benefit will be gained. In contrast, if drivers of vehicles with ESP modify their driving behaviour (e.g. by manoeuvring at higher speed or carrying out rapid lane change manoeuvres), then ESP may deliver a smaller safety benefit than predicted. This effect is often referred to as "risk compensation". This issue is not well understood and the very limited field data available which refers specifically to ESP can neither support nor refute the existence of risk compensation.

The existence of the EACS provided a new tool for investigating the first part of the proposed assessment. And the results suggest that ESP has the "opportunity" to influence a significant proportion of loss of control accidents.

However, a few observations need to be made about the use of EACS data for making estimates of this nature.

Firstly, EACS data is collected by many expert investigators working in different institutes in different countries. These institutes may have different objectives and methodologies for performing accident investigations and the data of EACS may therefore not be consistent, particularly for the analytic variables where the experts’ judgement is required. This applies particularly in the case of the variable concerning ESP effectiveness. EACS addresses this concern by having several investigators working on the same case and by regular workshops, training exercises and communications between the teams. Further experience is needed before the size of this effect can be estimated.

Secondly, EACS is not representative of all accidents occurring in Europe. Only six countries participate to the research program and, in each country, the investigation area is not representative of the national accident pattern. For example, 70% of EACS accidents occur outside urban areas whereas it is suspected that in Europe this percentage is much lower (for example, in France this percentage is close to 30%). Knowing that ESP is likely to be more effective on bends outside urban areas where drivers speed up, the rough estimate of ESP effectiveness coming from EACS data may be overstated. An alternative way of using the EACS data at this time is to treat the database as a "library" of anecdotal cases with full reconstructions which could be used in the development and validation of active safety systems such as ESP.

Thirdly, although EACS data show a very high initial estimate of the potential benefit of EACS, it should be noted that potential benefits estimated this way usually give high results (e.g. expected benefits of intelligent cruise control of 7.5% in California whereas rear end accidents are far less prevalent than loss of control accidents[19]) which are frequently reduced by subsequent fleet studies. A natural continuation of this study would be a fleet study comparing accident rates of ESP equipped and non equipped cars to confirm (or otherwise) the initial estimates coming from EACS.

Other predictions of the potential effectiveness of ESP have been performed by Zobel[20] and Langwieder[21,22].

Zobel suggested that one key benefit of ESP is to transform high risk side impacts (e.g. pole impacts) into frontal impacts with lower associated injury risks. He suggests that the effectiveness of ESP in these cases can be ascertained using existing in-depth injury sources. He cautions however, that these predictions are conservative (i.e. pessimistic) since they take no account of the ability of ESP to avoid impacts altogether. He therefore develops an "upper bound" based on the number numbers of impacts which are preceded by skidding. It is claimed that the true benefits of ESP lie between these extremes. He concludes that ESP could be expected to be "highly effective" provided that the driver is prepared to "accept the assistance offered by ESP with due caution".

Langwieder examined a large number of car-to-car and single vehicle accident cases. His analysis showed that loss of control and subsequent impacts represented a higher than expected proportion of serious injury accidents. He suggested that "modern driver assistance systems" (such as ESP) would not only facilitate driving but also reduce accident risk. He highlighted the particular situation where loss of vehicle control resulted in high risk side impacts. ESP could be expected to eliminate these accidents or change the configuration into lower risk frontal impacts.

CONCLUSIONS

This paper discussed the potential benefit of ESP, an active safety system aimed at preventing loss of vehicle control.

A new database, EACS (the European Accident Causation Survey) was used for the first time to estimate the potential opportunity for an active safety system based on the number of accidents in which it is judged that the presence of the system would have influenced the outcome.

The EACS data suggest that ESP could have a probable or definite influence in about 67% of fatal accidents involving loss of vehicle control and 42% of the corresponding injury accidents.

However, some cautions about potential effectiveness estimates produced in this way have been raised. In particular, data consistency between teams in different countries and lack of national or international representivity in the EACS sample were identified as particular concerns.

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