THE EFFECTIVENESS OF ESC (ELECTRONIC STABILITY CONTROL) IN REDUCING REAL LIFE CRASHES AND INJURIES

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ABSTRACT

ESC (Electronic Stability Control) was introduced on the mass market in 1998. Since then, several studies showing the positive effects of ESC has been presented.

In this study, data from crashes occurring in Sweden during 1998 to 2004 were used to evaluate the effectiveness of ESC on real life crashes. To control for exposure, induced exposure methods were used, where ESC-sensitive to ESC-insensitive crashes and road conditions were matched in relation to cars equipped with and without ESC. Cars of similar or in some cases identical make and model were used to isolate the role of ESC.

The study shows that the positive and consistent effects of ESC overall and in circumstances where the road has low friction. The overall effectiveness on all injury crash types except rear end crashes was 16.7 +/- 9.3 %, while for serious and fatal crashes; the effectiveness was 21.6 +/- 12.8 %. The corresponding estimates for crashes with injured car occupants were 23.0+/-9.2% and 26.9+/-13.9%.

For serious and fatal loss-of control type crashes on wet roads the effectiveness was 56.2 +/- 23.5 % and for roads covered with ice or snow the effectiveness was 49.2+/-30.2%. It was estimated that for Sweden, with a total of 500 vehicle related deaths annually, that 80-100 fatalities could be saved annually if all cars had ESC.

On the basis of the results, it is recommended that all new cars sold should have ESC as standard equipment.

BACKGROUND

The Electronic Stability Control, ESC or ESP, is an on-board car safety system, which enables the stability of a car to be maintained during critical manoeuvring and to correct potential under steering or over steering (1). In a general sense the equipment should eliminate loss of control. Since 1998, when the first mass-produced car with ESC standard equipment was launched, the market for cars with ESC has grown quickly. In Sweden, the proportion of new car sales equipped with ESC has grown from 15% in March 2003, to 69% in Dec 2004.

ESC operates normally with both brakes and engine management. If the car loses control, defined as when one wheel or more is moving faster or more slowly than calculated from the steering input and turning angle, braking is applied to one or more of the wheels, and the engine power might be reduced.

It has been expected, that the ESC will have a significant effect on loss of control type crashes. This effect is expected to have an influence both on the number and the severity of impacts (1), and might also change the orientation of the vehicle prior to impact (2, 3, 4). A projection of the effects based on in-depth data suggests that in 67% of the fatal and 42% of injury only crashes where the driver lost control, ESC would have a probable or definite influence (1). For all injury crashes, the estimated proportion of crashes addressed is 18%, for fatal crashes 34%.

Several studies have been presented, demonstrating the effectiveness of ESC in real life crashes. A Swedish study (5) presented in May 2003 showed that there was a positive influence of ESC, especially in crashes on wet surface or surface covered by ice or snow. The effectiveness ranged between 20% and 40%, all being significant.

Aga and Okado (6) showed that crashes dropped by 30 % to 35 %, and a German study (7) from 2002 showed a similar effect of ESC.

Unselt et al (8) demonstrated a 30% reduction of crashes where the driver was at guilt and a 40% reduction of loss of control crashes.

Two American studies have shown major effects of ESC. A NHTSA study (9), preliminary results show a 35% reduction of single vehicle crashes for passenger cars, and for fatal single vehicle crashes with 30%. Corresponding figures for SUVs were 67% and 63% respectively.

Farmer (10) show similar results with a 34% reduction overall of fatal crashes.

Other studies also express positive results (11, 12)

While ABS (anti-locking brakes) also was subjected to high expectations prior to being available, several studies have shown that the effects are minor, or close to none (13, 14). While the crash type distribution has been found to be different for cars equipped with ABS compared to cars without, the net effect is probably less than 5% reduction of crashes with injuries (13, 14). With ESC, the situation seems to be different, with high expectations prior to real life experience but with high and consistent effectiveness in studies of real life crashes so far.

The aim of the study was to:

- Present a method and apply it to estimate the influence of ESC on crashes in Sweden
- Estimate a possible reduction of real life crashes with injuries and for serious and fatal injuries separately.

METHOD

In this study, induced exposure is used to estimate the exposure to crashes for cars equipped and not equipped with ESC. This is an accepted method to use in situations when it is not possible to calculate the true exposure (13, 15, 16). The method is based on the identification of at least one type of event that is not expected to be affected by ESC. For that specific case, the crash number relation between ESC and not ESC would be considered as the true exposure relation. Any deviation from the established basic distribution for crashes not affected by ESC is considered to be a result of the equipment of ESC. The method is also considered to be based on the fact that there are no other differences between cars equipped and not equipped with the system under study (ESC), or any other user related factor that would alter the expected equal distribution of events and crashes. Both these prior factors are normally complicated to fulfil and control. In the present study, not only type of crash but also the surface condition was used to estimate possible effects. In the purest form, the effectiveness is calculated by

$$E = (A_{ESC} / N_{ESC}) / (A_{nonESC} / N_{nonESC}) \quad (1).$$

Where E is the effectiveness of ESC on crashes sensitive to ESC. A is the number of crashes sensitive to ESC, and N is the number of crashes considered not sensitive to ESC.

The standard deviation of the effectiveness was calculated on the basis of a simplified odds ratio variance (3). While this method gives symmetric confidence limits, the effectiveness is not overestimated. The formula is given below

$$Sd = E\,(SQR\,(SUM\ 1/n)) \quad (2).$$

Where n is the individual number of crashes of each type. The confidence limits are 95%.

A critical part of the method is to choose and identify cars that are identical in every other factor than the presence or absence of ESC. This is in reality very complicated, as ESC is firstly not a random equipment, but has sometimes to be ordered separately or was introduced in a sequence where none of the vehicles of a particular model had ESC, and after a certain date, all had. The third possibility is when a vehicle has ESC as standard equipment on some of the versions of a model range, often linked to other differences. There is no record of ESC equipment kept in the register of vehicles in Sweden. In this study, the focus has been on finding two sets of vehicles, with and without ESC, where ESC was introduced as standard equipment at a certain point in time. The benefits are that the selective bias in picking ESC as option, or choose a car with higher specifications, are avoided. On the other hand, a car with and without ESC has not been subjected to the same conditions otherwise. If the same time is picked for the analysis, the cars without ESC is on average older than cars with ESC, or if the age of the cars is identical, the time at which they were exposed is not the same. It is, however, not impossible to control for these confounders, as the history for the cars without ESC could be analysed as to what happens when the car gets older.

In this study, products mainly from Mercedes-Benz, BMW, Audi and VW were included in the analysis as case cars. The majority of the cars picked would be classified as more upmarket models, but there are some that would be considered as models attracting a wider part of the market, such as MB A-Class, Audi A3/A4 and VW Passat.

The other critical part of the method is to pick crash types and/or road surface conditions that are considered to be insensitive to the effect of ESC. It is important that this part is done a priori to the analysis. The approach used in this study was to use the results of a European multi centre assessments of where ESC would have an impact (1). In the European multi centre study, expert teams assessed on a number of in-depth studies in a scaling system how much ESC would have contributed. It was found, that crashes in intersections would not have been benefited much by ESC, while other types of crashes would have been affected to a varying degree. Also, lower friction, in this case rain, is a risk factor.

In the present study, rear end impacts on dry surface were considered insensitive, and both wet roads as well as roads with snow and ice were treated separately. The reason for picking only rear end impacts was that it is one of a few crash types that alone on just dry road conditions would constitute enough cases to be used. Logically, it is also a crash type that would not involve much of vehicle handling factors. This is an even more limited crash type than proposed by the study mentioned above, which has the advantage that effects of ESC could be picked up over a more varied set of crash types. A broader set of crash types would have limited the possibility to estimate the overall effect of ESC. The disadvantage by not disaggregating the effects on individual crash types is obvious, but the data set was not large enough to allow such a detailed analysis.

MATERIAL

The data set was constituted by police reported crashes with at least one injured person in Sweden. All crashes from the years 1998 to 2004 was used to select crashes with vehicles from model year 1998 to 2005. All crashes recorded by the police contains at least on injury. From vehicle model codes the car models with electronic stability program (ESC) were specified. Matched controls were identified also by the model codes. The controls were selected to be as close as possible to the case vehicles. In many cases the same model or model platform was used as control. Appendix 1 shows the vehicle models used in this study. In all 1942 crashes with ESC equipped cars were found. The control group contained 8242 crashes. For every crash the road condition, dry, wet or snowy/icy was used together with the collision type. The deformation pattern of the vehicles were also used. The cars used can be seen in appendix 1.

The data set contained fatalities (42 case and 179 controls), severe injury cases (294 case and 1319 controls) and minor injury crashes (1609 cases and 6774 controls).

While police reported crash data is known to suffer from a number of quality problems, none of them is likely to influence the findings of this study to any large degree.

RESULTS

The results are based on the assumption that rear-end crashes on dry roads are not, or only slightly, affected by the presence or absence of ESC. Both ESC vehicles and the selected controls are all equipped with ABS, so there should not be any influence of such a factor.

The results presented were based on a selected sample of control cars. There was also a control calculation performed using all post 1998 car model vehicles and their crash distribution. This control group and the used matched control group show an almost identical distribution of rear end crashes to other crashes, as well as the distribution of crashes on the three road surface types used in this study. The selected and used control group therefore does not seem to differ from the rest of the car population, and the case group does not differ from the control, group in the crash type that is used as the exposure basis (rear end collisions on dry road surface).

In table 1, the calculated effectiveness of ESC for crashes with injuries and for crashes with serious outcome (serious and fatal injuries) are presented. These cases include crashes with unprotected road users. Estimates for crashes only involving car occupants are given separately. It can be seen, that all reductions are significant. It can also be seen, that for serious and fatal injuries for car occupants, the reduction is at least 13% (lower 95% confidence limit). While it is understood that this estimate reflects on the total outcome, ESC is likely to be only relevant for some crash types and for some road conditions.

Table 1.
The effectiveness of ESC on crashes with personal injuries. 95% confidence limits. All estimates are reductions in relation to rear end impacts

All crashes excl rear end	16.7% +/- 9.3%
All crashes excl rear end, car occupants	23.0% +/- 9.2%
Serious/fatal crashes excl rear end	21.6% +/- 12.8%
Serious/fatal crashes, excl rear end, car occupants	26.9% +/- 13.9 %

In table 2, the estimates for single car, oncoming and overtaking crashes are given. It can be seen, that the effectiveness is higher, than for crashes overall. The highest effectiveness is related to single vehicle crashes with serious/fatal outcome.

Table 2.
The effectiveness of ESC on crashes with personal injuries, by crash type. 95% confidence limits. All estimates are reductions in relation to rear end impacts on dry road surface

Single, oncoming and overtaking casualty crashes	31.0% +/-10.2%
Single, oncoming and overtaking serious/fatal crashes	40.7% +/-15.1%
Single serious/fatal crashes	44.4% +/-19.6%

Table 3.
The effectiveness of ESC on crashes with serious and fatal injuries, by road surface. 95% confidence limits. All estimates are reductions in relation to rear end impacts for related road surface

Single/oncoming/overtaking crashes, dry surface	24.8% +/- 26.0%
Single/oncoming/overtaking crashes, wet surface	56.2% +/- 23.6%
Single/oncoming/overtaking crashes ice/snow surface	49.2% +/- 30.2%

In table 3, ESC related crashes for different road surfaces, are given. While the effectiveness on dry surface is not significant, the reduction for serious and fatal crashes on wet and surface covered by ice or snow is large and significant. For the low friction surfaces, the reduction is in the order of 50%. Treated together, the best estimate for all surfaces except dry, is 53+/-18%, demonstrating a minimum of 35% reduction.

A best estimate for fatal outcome in the same type of crashes is also 53%, but with larger confidence limits (+/-45%) as a result of the smaller material.

A separate analysis was made to evaluate if there are any major differences as to where cars with and without ESC has a deformation pattern that differ. This was done for both all crashes, as well as for single vehicle crashes. No difference was found.

DISCUSSION

Electronic Stability Program (ESP) or Electronic Stability Control (ESC) is a new technology, brought into the mass market in 1998. Some studies (1, 2, 3, 4) predicted a positive outcome, but it was not until late 2002 (7) and early 2003 (5, 6), that the first results from real life crashes were reported. At this stage, the results were more positive than expected given the experience with other primary safety systems (13, 14).

Since then, several studies (8, 9, 10, 11 and 12) have demonstrated similar positive results from ESC. While the results have been related to studies with varying selection criteria, study type and effectiveness estimates, all studies show a positive and large effectiveness. Another strength is the fact that the data has been collected in different countries and with different set of vehicles. Still, there is a need to continue to validate earlier results and evaluate long term effectiveness. The amount of studies and the clear and consistent results show, however, that there is no fundamental problem in evaluating primary system effectiveness with robust statistical techniques.

At this stage, evaluations can only be made on the basis that all ESC systems and for all car models, have the same effectiveness. Two studies from the US (9, 10) have been able to separate passenger cars from SUV, but it is likely that there are also other differences that are important. There is a development ongoing in making ESC more sophisticated and covering more situations. This is done without knowing what characteristic of ESC that is mostly safety related, and therefore the understanding of the impact of more sophisticated systems must be done by empirical evaluation of real life crash data.

The method used for this study has been used in many other types of evaluations (13, 14). It is a method that is dependent on a number of assumptions and critical factors. It should be understood, that new vehicle technology is not brought into the market in a way that would guarantee a scientific evaluation. First of all, the technology is not randomly equipped to vehicles, and there is probably a selective recruitment to such technology. Secondly, in the early stages of implementation, ESC seemed to be brought to the market on more up-market car models, and vehicles in high-performance versions. Attempts have been made in this study to overcome this problem, but there are still some doubts about how the technology is picked up by consumers. The novelty of the technology might even lead to, that drivers of cars with such technology will provoke the system to act, or that there are some behavioural modifications. These phenomena are very hard to control for, but might modify the long-term effectiveness of ESC or similar technologies. In the present study crashes with cars sold as early as 1998 were included, with no detectable difference over the time period.

The method used in the present study, does not allow an analysis on the actual function of the system, and in what sequence of driving it has its potential. Whether ESC works as an intelligent system to warn the driver about low friction, or if it has a direct function in the driver-vehicle loop in critical manoeuvres, either in controlling stability and/or reduce speed, was not possible to study. It could be expected that the functionality of the system has an impact, as for example, ESC insensitive crashes for cars with and without ESC seem to happen with the same distribution over different road surfaces. If ESC was most effective in warning for low friction, it is likely that also other crash types on low friction were affected. This was not the case in this study.

It has been mentioned earlier (2), that ESC could have an effect on the direction and location of impact. A higher proportion of crashes would be expected to be frontal rather than lateral. In this study no such effect could be found.

This study, as well as studies from others, shows clearly that ESC has a very high potential in saving lives and injuries. In this study, the number of crashes where car occupants are severely injured or killed, the effectiveness is over 25%. In crashes that are more ESC sensitive, like single/oncoming/overtaking crashes on wet or icy roads, the reduction is in the order of 50%. This is more than most other safety systems, except from the use of seat belts. If a new technology like ESC was brought into the whole car population, this would have a major impact on the total losses in the road transport system. It is therefore essential, that ESC is brought in as one of the key strategic instruments to fulfil high ambitions in road safety programmes across the world. This was done in Sweden already in 2003, with a firm recommendation to the public. At that stage, the fitment rate on new cars was 15%. In September 2004, 16 months later, the fitment rate was 58%, and a stronger recommendation was given. In December 2004, the fitment rate on new cars had grown to 69%. This is probably one of the highest in the world. The other Nordic countries have fitment rates varying from 30% to 40% (source Bosch) while for Europe as a whole, there are countries with fitment rates as low as 10%. A strong action from the society, media and consumer groups is probably an important factor. There is at this point no reason not to recommend all consumers to choose a car with ESC, and to advise car manufacturer to only market cars with ESC as soon as possible.

CONCLUSIONS

- ESC was found to reduce crashes with personal injuries, especially serious and fatal injuries.

- The effectiveness ranged from at least 13% for car occupants in all types of crashes with serious or fatal outcome to a minimum of 35% effectiveness for single/oncoming/overtaking serious and fatal crashes on wet or icy road surface.

RECOMMENDATIONS

- Consumers should be recommended to buy cars with ESC, and automotive industry should only market cars with ESC as quickly as possible. Such a policy statement has increased the fitment rate on new cars in Sweden to almost 70% in less than two years.

- Further studies should be made, to validate the results of the present study, and increase the understanding of the mechanism of the improvement.

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APPENDIX CAR MODELS USED

Case car models	Cotrol car models	Case cars	Control
ALFA ROMEO 156	ALFA ROMEO 156	17	45
ALFA ROMEO 166	ALFA ROMEO 166	4	6
AUDI A2		24	
AUDI A3	AUDI A3	63	220
AUDI A3 2	AUDI A4	8	381
AUDI A4		63	
AUDI A4		138	
AUDI A6	AUDI A6	71	380
BMW 3-SERIES	BMW 3-SERIE	117	201
BMW 5-SERIES	BMW 5-SERIE	14	222
BMW 5-SERIES 2		91	
BMW 7-SERIES		2	
BMW X3		5	
BMW X5		16	
BMW Z3	BMW Z3	5	8
BMW Z4		1	
CITROËN C5	CITROËN C5	32	54
FORD MONDEO	FORD MONDEO	29	169
MAZDA 6		24	
MERCEDES-BENZ A-CLASS		129	
	MERCEDES-BENZ C-CLASS 202		86
MERCEDES-BENZ C-CLASS 203	MERCEDES-BENZ C-CLASS 203	19	63
MERCEDES-BENZ CLK	MERCEDES-BENZ CLK	7	35
MERCEDES-BENZ E-CLASS W210	MERCEDES-BENZ E-CLASS W210	423	363
MERCEDES-BENZ E-CLASS W211		52	
MERCEDES-BENZ S-CLASS		2	
MERCEDES-BENZ S-CLASS 2		14	
MERCEDES-BENZ SLK		8	
MITSUBISHI PAJERO	MITSUBISHI PAJERO	13	47
OPEL VECTRA	OPEL VECTRA	8	18
PEUGEOT 206	PEUGEOT 206	84	294
PEUGEOT 307	PEUGEOT 307	49	70
PEUGEOT 406	PEUGEOT 406	11	268
PEUGEOT 607	PEUGEOT 607	20	4
SAAB 9-3	SAAB 9-3	9	111
SAAB 9-5	SAAB 9-5	44	1191
TOYOTA COROLLA	TOYOTA COROLLA	16	96
VOLVO S40/V50	VOLVO S40	27	1638
VOLVO XC90		15	
VW GOLF 4	VW GOLF 4	20	983
VW GOLF 5		15	
VW PASSAT 4	VW PASSAT 4	218	1119
VW SHARAN	VW SHARAN	10	170
VW TOURAN		5	
Sum	**Sum**	**1942**	**8242**