REAL-WORLD ASSESSMENT OF RELATIVE CRASH INVOLVEMENT RATES OF CARS EQUIPPED WITH ELECTRONIC STABILITY CONTROL

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ABSTRACT

This report has evaluated the reduction in crash involvement of cars equipped with Electronic Stability Control (ESC) systems. The evaluation has been conducted for all crashes as well as for a variety of road and loss of control conditions. In addition, a study of ESC benefits in terms of crash costs and accidents prevented has been undertaken. The results show that ESC effectiveness is 3% in crashes of all severity. Serious crashes are 19% lower compared to non-ESC cars and fatalities 15% lower. The potential annual savings in accident costs for a 100% take up of ESC amounts to 588 million pounds by preventing some 5212 crashes. Overall, ESC has shown worthwhile reductions in both accident frequency and cost across a wide variety of crash situations.

INTRODUCTION

In order to effectively direct future policy-related improvements in vehicle design it is important to gain feedback on previous changes to vehicle design. The development of secondary safety technologies is bases on a sound knowledge of vehicle structure and restraint system design and human bio-mechanics. However when intelligent technologies are intended to prevent crashes occurring there are factors which are less well known. Electronic stability control systems have been developed to increase the level of control over vehicle dynamic performance. Comparison of steering wheel heading and front wheel direction allows over-steer or under-steer to be identified and corrected by applying braking on the appropriate wheel. While these systems demonstrate good levels of performance under test conditions their use in the real-world can involve the possibility that other confounding factors may reduce the effectiveness. Examples include the possibility that drivers may change their driving style in response to the increased capability of the system, that real-world driving conditions may be different from the tests or that the electromechanical systems may not function in the manner observed in tests. It is therefore essential to evaluate the performance of new systems once they are on the road.

Several authors have analysed the crash rates of cars equipped with ESC to compare with non-ESC vehicles. These values vary significantly and are listed below in Table 1

Table 1:.
Summary of ESC effectiveness studies

Study	Approach	Crash type	Effecti-veness
Sferco[1]	Predicted influence Predicted influence	Fatal crashes Serious crashes	34% 19%
Langwieder [2]	Predicted effectiveness	Skidding crashes	60%
Becker [3]	Measured effectiveness	All crashes	45%
Aga and Okada [4]	Measured effectiveness	Single vehicle	35%
Tingvall[5]	Measured effectiveness Measured effectiveness	All crashes Wet/icy roads	22% 17%
Farmer[6]	Measured effectiveness Measured effectiveness	Single vehicle Multi-vehicle	41% 0%
Dang[7]	Measured effectiveness Measured effectiveness	All car crashes All SUVs	30% 67%
Thomas[8]	Measured effectiveness	All crashes	3%

It is clear from Table 1 there is no standard way of describing the effectiveness of a system and this means it is difficult to compare results. The only firm conclusion is that ESC systems appear to uniformly give a positive contribution to crash prevention but it is not clear what that level should be nor under what conditions. Thomas (2006) analysed the Great Britain casualty data for the years 2002 to 2004 and concluded the overall reduction of crash involvement of cars equipped with ESC was 3%. This result was substantially lower than the experience of other countries and against this background it was decided to re-

evaluate the GB results using accident data gathered in the years 2002 - 2005.

METHODOLOGY

Crashes that occur in Great Britain resulting in injury and reported to the police are recorded on the national register known as Stats19[9]. The data for 2002-2005 were matched to vehicle licensing information so that car make, model, variant and year of manufacture was known. Information on ESC fitment was matched in using data from the Glass's Guide Checkbook, 2005[10]. A subset of this data was selected to include all injury accidents in which a car was involved. Crashes where a pedestrian, motor cycle or bicycle was involved were excluded. This is because these vulnerable road users tend to dominate the injury severity of the crash.

The analysis uses a case-control method based on the induced exposure method (Evans, 1986 [11]). Case vehicles were defined as those known to be equipped with ESC. A comparable group of control vehicles not fitted with ESC were also defined. These were, in general the previous version of a case vehicle. The make and model of case and control vehicles are shown in appendix B. There were 10,475 case vehicles and 41,656 control vehicles in the dataset. This represents a 21% increase in ESC equipped cars compared with the earlier study.

The case control method also requires vehicle manoeuvres to be separated into those where ESC may have an effect and those where no ESC effect is assumed. Table 1 shows how these case and control manoeuvres were defined.

Table 2

Case and Control Manoeuvres

Control Manoeuvre (no ESC effect assumed)	Other Manoeuvre (ESC effect possible)
Reversing	U turn
Parked	Turning left
Waiting to go ahead but held up	Turning Right
Stopping	Changing lane to left
Starting	Changing lane to right
Waiting to turn left	Overtaking moving vehicle on it's offside
Waiting to turn right	Overtaking stationary vehicle on it's offside
	Overtaking on nearside
	Going ahead left hand bend
	Going ahead right hand bend
	Going ahead other

Using the case-control method, cars in the sample were distributed between the four case control categories shown in table 3.

Table 3.
Case and Control Contingency Table

	Control Manoeuvre (assumed no ESC effect)	Other Manoeuvre (ESC effect possible)
Case Vehicle (ESC)	N_{00}	N_{01}
Control vehicle (no ESC)	N_{10}	N_{11}

The method then calculates the odds of a case vehicle being involved in either of the two crash types (1) and the odds ratio is used to compare the two groups of cars (2). The effectiveness of ESC is defined in (3) and the standard deviations are calculated as shown in (4).

(1) Odds_{ESC} (Control/Case) = N_{00}/N_{01}

(2) Odds ratio = ($\text{Odds}_{ESC}/\text{Odds no}_{ESC}$) = N_{00}/N_{01} N_{11}/N_{10}

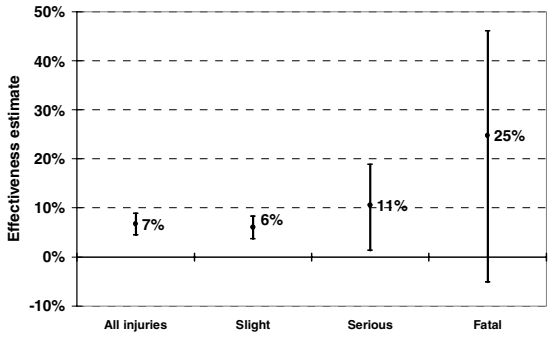
(3) $\text{Effectiveness}_{ESC}$ = (1 – Odds ratio)100%

(4) SD = Odds ratio x exp ($\sqrt{[1/N_{00} + 1/N_{10} + 1/N_{01} + 1/N_{11}]}$)

RESULTS

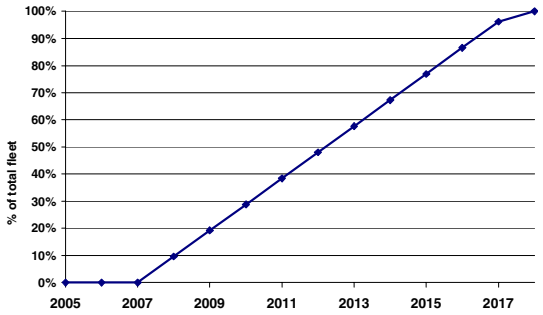
The reductions in crashes for severity groups is shown in Figure 1. Overall cars with ESC fitted were involved in 7% fewer collisions than non-ESC cars. Fatal crashes were reduced by 25% although this was non-significant and the serious injury group decreased by 11%.

Figure 1.
Reduction in crashes with ESC



The UK car fleet includes 26,000,000 cars and each year 2,500,000 new cars enter the fleet. Based on the conservative assumption there were no ESC cars on UK roads in 2005 Figure 2 shows the increasing proportion in the fleet that is expected to be ESC equipped if all new cars from 2008 were ESC equipped.

Figure 2.
Projected fleet penetration of ESC equipped cars



The projection indicates that effectively full fleet penetration would be achieved by 2018.

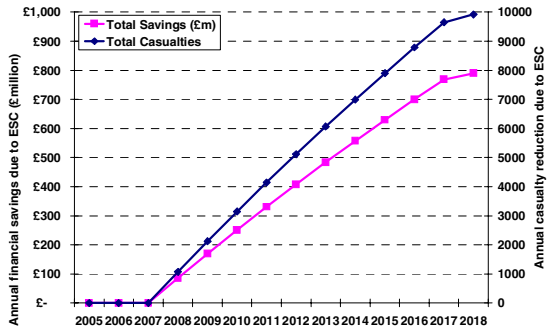
The projected casualty and financial savings can be projected based on the fleet penetration information and also on the true casualty numbers of occupants in cars. The UK, like many other countries has declining numbers of traffic casualties Table 4 shows the average annual reduction since the current baseline values of the 1994-8 average. Fatal casualty numbers have reduced by a mean of 0.5% each year while the drop for all casualty severities is 1.2%pa.

Table 4.
Mean annual casualty reduction over 1994-8 baseline

Total car occupants	1994-8 average	2005	Mean annual decline from 1996
Killed	1,762	1,675	0.5%
Serious	21,492	12,942	4.0%
Slight	180,034	163,685	0.9%

Figure 3 shows the result of combining the existing casualty reduction rates with the increasing fleet penetration of ESC equipped cars to estimate the reduction in total casualties due to the increasing ESC numbers in the fleet. The figure also shows the financial savings based on the standard UK model using willingness to pay methods.[12].

Figure 3.
Annual casualty and financial savings with ESC



When full fleet penetration is achieved by 2018 ESC systems are projected to be reducing total casualties by 9919 each year, including 388 fatalities, compared to the baseline of no ESC in the fleet. The value of these savings, taking account of the different costs for each severity level, equal £790 million (€1,100 million) each year (2005 prices).

Table 5 shows the projected numbers of each injury category in 2008 and 2018 when all cars in the fleet are expected to be equipped with ESC for the two groups assuming there is no further increase in ESC equipped cars and assuming that all new cars from 2008 will have ESC.

Table 5.
Casualty reduction projections

	Total without further ESC		
Year	**Slight**	**Serious**	**Fatal**
2008	159305	11450	1650
2018	145535	7613	1569

	Reduction with ESC		
Year	**Slight**	**Serious**	**Fatal**
2008	919	116	39
2018	8732	799	388

Figures 4 to 6 show the effectiveness of ESC according to different road surface conditions.

Figure 4.
ESC Reduction for Wet Road Surfaces

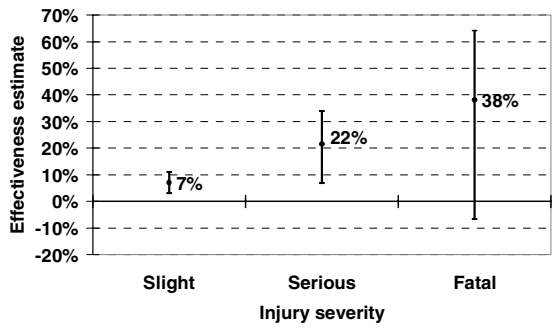


Figure 5.
ESC Reduction for Dry Road Surfaces

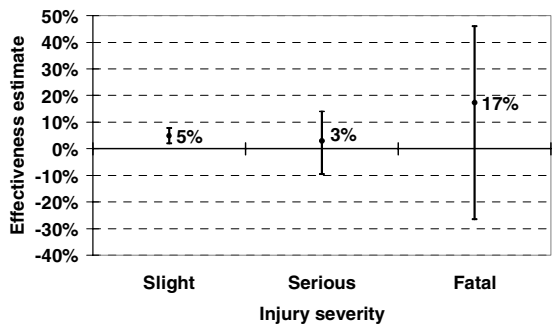


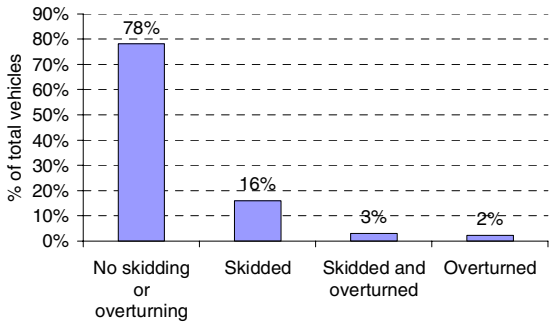
Figure 6.

ESC Reduction for Snowy and Icy Road Surfaces

The overall reduction of crashes for ESC equipped cars on dry road surfaces was 5%, on wet roads it was 9% and on snow or icy surfaces it increased to 20%. On all road conditions the reductions were greater for the more severe injury outcomes although there were insufficient cases to form an estimate of fatal crashes on snow and icy surfaces. Despite the greatest effectiveness of ESC `being observed under the more adverse road conditions these were seldom associated with crashes in the GB data. Figure 7 shows the frequency with which these conditions were associated with crashes in the accident data..

ESC EFFECTIVENESS IN SKIDDING AND ROLLOVER Skidding or rollover generally indicate a loss of control situation. The incidence of these factors in the crash sample is shown in figure 7 and the changes in crash involvement of ESC equipped cars is shown in figures 8 and 9. Figure 7 shows that the majority (78%) of crashes did not involve skidding or overturning. Skidding alone occurred in 16% of crashes and overturning was rare in only 5% of crashes.

Figure 7.
Distribution of Skidding and Overturning



Where skidding alone was involved ESC equipped cars were 23% less likely to be involved in crashes of all severities. The corresponding value for overturning crashes was higher at 36%. Figures 8 and 9 also indicate that ESC was beneficial in

serious injury crashes showing effectiveness values of 33% for skidding related events and 59% for overturning crashes. Values for fatalities are not shown for either condition due to very wide error bands and low numbers of cases.

Figure 8.
ESC reduction in Skidding Related crashes

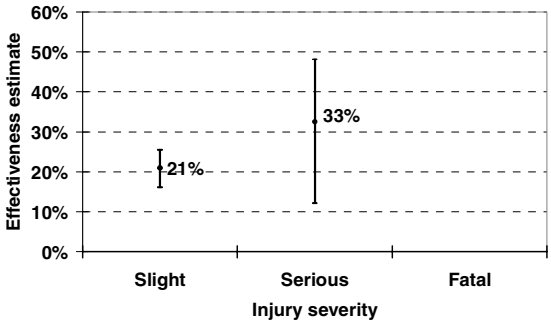
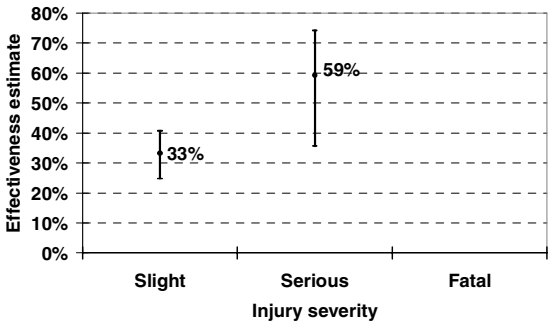


Figure 9.
ESC Reduction in Overturning Crashes



ESC EFFECTIVENESS IN SINGLE VEHICLE CRASHES Single vehicle crashes are those that involve only one vehicle but may involve a pedestrian. The crashes analysed here do not include pedestrians because of their domination of the crash severity outcome. Figure 10 shows the distribution of single vehicle compared to multi vehicle crashes. Crashes involving only one vehicle are in the minority at 8%. Figure 11 shows effectiveness rates for cars equipped with ESC in single vehicle crashes. Overall effectiveness is 27% dropping to 17% for slight crashes. The high value for serious crashes (91%) should be viewed with caution as it is based on only 1 control vehicle and 2 case vehicles in a control manoeuvre situation while no vehicles were present in that situation for fatal crashes.

Figure 10.
Numbers of Vehicles Involved in Crash

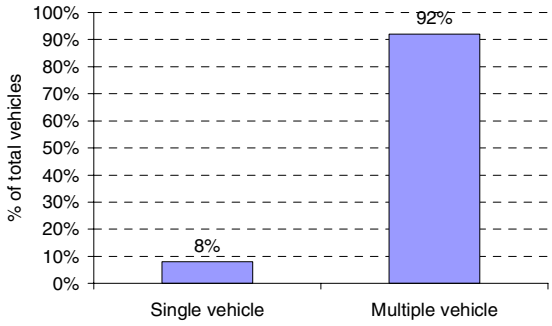
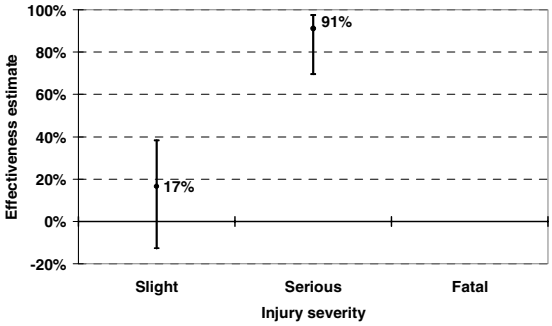


Figure 11.
ESC Reduction in Single Vehicle Crashes



ESC EFFECTIVENESS AND GENDER Figure 12 shows the distribution of driver gender in the sample. Males are in the majority at 70%. For males, ESC showed an effectiveness of 7% for all severities of crash. Figure 13 shows an increasing ESC effectiveness with injury severity. 6% for slight injury, 10% for serious injury and 48% for fatals. For females (figure 14), overall effectiveness was 5% and the values for slight and serious crashes were not significantly different to those for males 4% and 15% respectively. The value for female fatalities was not significant due to small case numbers.

Figure 12.
Distribution of Driver Gender

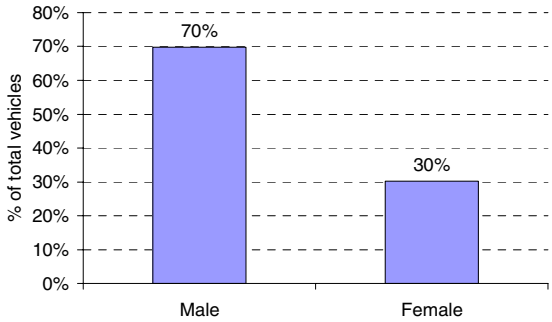


Figure 13.
ESC Reduction in Cars with Male Drivers

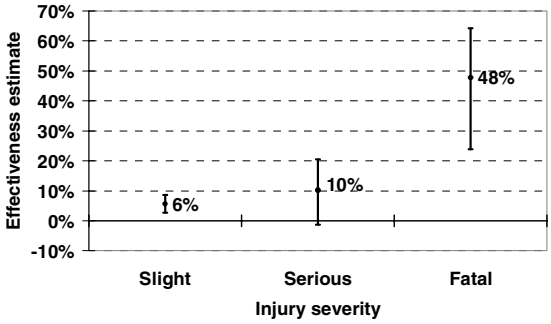
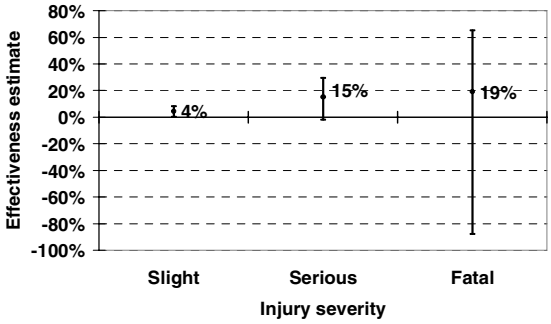
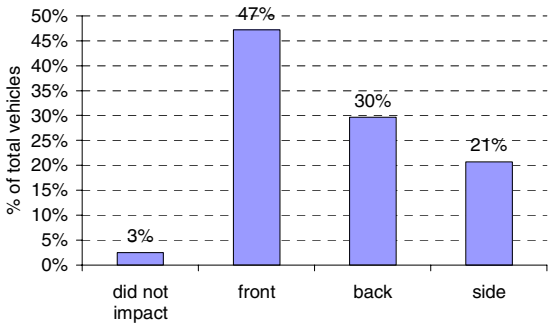


Figure 14.
ESC Reduction in Cars with Female Drivers



ESC EFFECTIVENESS IN FRONT AND SIDE IMPACTS The GB national casualty dataset includes an assessment of first point of impact on the vehicle. Figure 15 shows that 47% of all vehicles sustained an impact to the front and 21% to the side. The case vehicles with ESC had a 10% lower rate of frontal collisions and a 9% lower rate of side collisions. So there was very little difference in overall effectiveness between front and side collisions.

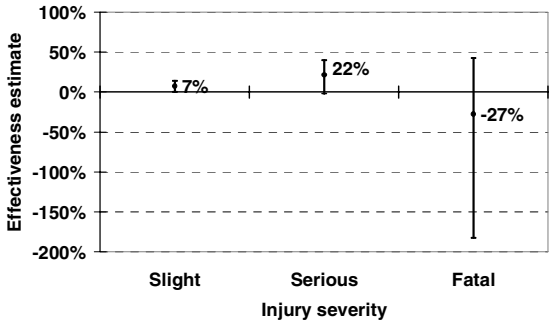
Figure 15.
First Point of Impact to Car



Figures 16 and 17 suggest that ESC may be more effective in side crashes when serious injury occurs. ESC equipped cars were involved in 22% fewer crashes in side impact compared to 2% in frontal crashes. Confidence limits for fatalities were large and negative for both impact types making effectiveness rates non significant.

Figure 16.
ESC Reduction in Front Collisions

Figure 17.
ESC Reduction in Side Collisions



DISCUSSION

This analysis demonstrates that cars equipped with ESC are involved in significantly fewer crashes than similar cars without ESC . The overall reduction on GB roads was 3.1% corresponding to 9,000 fewer crashes each year with a corresponding cost to GB of £559,773,000 at 2004 rates. Under adverse road conditions the effectiveness is greater rising to 25% on snow or icy roads although such crashes only account for 2% of GB crashes.

LIMITATIONS

There are limitations to this analysis since there may be other significant differences in handling between case and control vehicles in addition to ESC systems. If these changes also improve the dynamic behaviour of the vehicle then the effectiveness of ESC alone would tend to be over-estimated. Additionally the chances of crash involvement will also be dependent on driving behaviour; if the case vehicle is a model preferred by drivers with lower risk acceptance the vehicles will not be exposed to comparable driving situations and again the effectiveness of ESC will tend to be over-estimated. This analysis has selected control cars that are as similar as possible to the case cars in order to minimise these effects but they can not be completely avoided. On the other hand the mis-classification of ESC equipped cars, whether in the case or control groups will tend to under-estimate the effectiveness of ESC. The matching of the ESC equipped data is dependent on

an accurate definition of the vehicle model. The matching has been done to the limits of the available data, on the basis of the make, model, variant, engine size and year of manufacture, but there may be a small number of cars misclassified. Kreiss et al[13] have shown that the effect of mis-classification is to consistently under-estimate the effectiveness of ESC so the effectiveness rates reported in this analysis have to be considered to be minimum values although it is expected that the opportunity for mis-classification has been small.

SUMMARY

One of the largest datasets of ESC equipped cars available has been analysed for this case-control study. It has shown that in general ESC equipped vehicles have a lower crash involvement rate and these are particularly high under adverse road surface conditions but there are classes of car and types of accident where benefits are reduced or negative. The results show that ESC effectiveness is 7% in crashes of all severity. Serious crashes are 11% lower compared to non ESC cars and fatalities 25% lower. The potential savings in accident costs for a 100% take up of ESC amounts to some £790 million pounds annually by preventing some 9919 crashes. Even at a 50% take up the saving amounts to some £395 million.

ESC appears to offer additional benefit in adverse road conditions. Overall effectiveness was estimated as 20% for icy conditions and 9% for wet conditions compared to 5% for dry roads. In terms of serious crashes however, ESC effectiveness appears even more pronounced, 22% for wet roads compared to 3% for dry. Skidding and overturning crashes are typical situations on bends when the driver enters too quickly and attempts to steer. The study suggests a high ESC effectiveness. 23% in all skidding related crashes and 36% in all overturning crashes. The corresponding values for serious crashes are 33% and 59% respectively.

There appears to be little difference in ESC effectiveness depending on whether a male or female is driving.

Effectiveness in serious side crashes is much higher (22%) compared to that in serious frontal crashes (2%). This is in line with work by Reiger et al (2005) which suggests that ESC preferentially prevent side impacts since they are more likely to involve loss of control. Single vehicle crashes are also those where ESC is often supposed to have a significant effect. Compared to non-ESC cars, 27% fewer ESC vehicles were involved in all single vehicle crashes compared to 7% for multi and single vehicle crashes taken together. Unfortunately case numbers did not allow a reliable assessment of ESC contribution to the reduction in serious single vehicle crashes.

Overall, ESC has been seen to show worthwhile reductions in both accident frequency and cost across a wide variety of crash situations. There are however, a number of factors to consider when interpreting these results.

Levels of ESC effectiveness in international studies are in many cases different, usually higher, than those seen in this study. This could be due to a different variety of road, driving and weather conditions as well as to differences in classification of crash severity and vehicle manoeuvres. It is therefore important that any decisions over mandatory fitting of ESC systems be taken on the basis of their overall effectiveness across a range of traffic environments.

The case-control method compares ESC and non-ESC cars in total and hence compares all the differences between case and control cars. It has been hypothesized that as all ESC cars have ABS systems, this may be the only reason for the differences in crash involvement. It is unlikely that this is the case as previous studies of ABS systems have shown the effects of ABS to be small Evans (1998) and Broughton (2002).

One important factor to consider when viewing results of this study is the part played in injury reduction due to improvements in passive safety of the cars. Generally, the cars in the control group were all equipped with airbags and structural improvements compared with cars designed before the introduction of the EU front and side impact Directives but there may have been further improvements introduced at the same time as ESC systems. There is no indication that passive safety improvements change driving behaviour that would influence the risk of crash involvement but the improvements could be expected to change injury outcomes. Whilst the reductions in killed and seriously injured occupants will represent the combined effects of reduced crash involvement and reduced injury risk, a passive safety system would be expected to give the same protection on a wet as a dry road under the same crash conditions yet there are very different risks of fatal and serious crashes in the data reported here. Although it was not possible to quantify the effects of passive safety improvements, the results in this study are considered largely to be a measure of improvements in handling performance – mostly ESC.

Every effort was made to compare cars that were as similar as possible so that the major difference was ESC fitment. It is possible that a few were misclassified, however, Kreiss et al (2005) have shown that the effect of misclassification will be to consistently underestimate the effects of ESC. It is

also likely that many crashes with slight injuries are not reported to the police as is the case with damage only events. In addition, we cannot tell how many crashes were avoided completely by the operation of ESC. In those respects, any estimates of ESC effectiveness shown in this study should be viewed as conservative.

The Great Britain national casualty data used in this analysis provides one of the largest samples of ESC equipped cars but further methodological procedures may be required to fully isolate the crash reduction benefits of the system.

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