Effectiveness of Electronic Stability Control Systems in Great Britain

PPAD 9/33/99 (C)

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SUMMARY

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 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 959 million pounds by preventing some 7800 crashes. Even at a 50% take up the saving amounts to some 480 million pounds.

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 effectiveness depending on whether a male of female is driving but effectiveness is serious side crashes is much higher (22%) compared to that in serious frontal crashes (2%). Single vehicle crashes are those where ESC is often supposed to have the greatest 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 shown worthwhile reductions in both accident frequency and cost across a wide variety of crash situations.

Section 1: BACKGROUND

Electronic stability control (ESC) is a system that utilises the electronic control of the brakes and engine to prevent the driver from losing control of the vehicle. It achieves this through a calculation of the driver's intended actions (measured through steering wheel angle, accelerator position and vehicle speed) and a comparison of the driver's intentions to the dynamic characteristics of the vehicle (taken from a lateral accelerometer and yaw rate sensor).

If the vehicle senses a difference between the "driver's intentions" and the actual path of the vehicle, it applies the brakes to individual (or all) wheels, and if necessary reduces engine power to change the behaviour of the vehicle. This prevents the front of the vehicle from "running wide" or the rear from sliding out in corners.

It is intended that ESC will be applied mostly in bends where the driver may lose control of the vehicle. This is likely when the driver is attempting to steer whilst the vehicle is skidding, or the driver enters a bend too quickly without applying the brakes. Electronic stability control systems have been in development since 1995 and are currently available for mass production.

Honda suggests that, by fitting an electronic stability control system, the risk of a vehicle being involved in a collision is reduced by 35%. Similarly, Daimler-Chrysler states that there has been a reduction in the incidence of collisions involving Mercedes vehicles since they introduced ESC as standard equipment in 1999.

Statistics from other international published papers support the adoption of ESC but show different rates of effectiveness.

- Sferco et al. (2001) – ESC could reduce the occurrence of 18% of all-injury and 34% of fatal collisions. (Germany).
- Langwieder. (2004) - ≥25% of all injury crashes and 60% of skidding crashes could be prevented by ESC systems (Germany).
- Aga and Okada. (2003) – a 35% reduction in single-car accident rates and a 30% reduction in head-on collision rates for ESC-equipped vehicles in comparison to those not equipped (Japan).
- Becker et al. (2004) – 45% of loss-of-control injury accidents could be prevented if all vehicles were equipped with ESC (Germany).

- Tingvall et al. (2004). Overall reduction in crashes of 22%. 17% on wet or icy roads (Sweden).
- Farmer. (2004). Reduction in single vehicle crashes of 35% but no effect on multi vehicle crashes (U.S.A).
- Dang (2004). 30% reduction in single vehicle fatalities. (U.S.A.).

Support for the adoption of ESC systems in UK vehicles will need to be based in part on the UK situation. The aim of this study was therefore to provide an assessment of the effect of the introduction of ESC systems to vehicles in the United Kingdom.

Section 2:
METHODOLOGY

Crashes which occur in Great Britain resulting in injury and reported to the police are recorded on the national register known as Stats19 (Road Casualties Great Britain, 2005). 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. A subset of this data was selected to include all injury accidents in which a car was involved. Crashes involving vulnerable road users, whether pedestrians, motor cycles or bicycles were excluded. This is because these vulnerable road users tend to dominate the injury severity of the crash and in general, such crashes are not those where we would expect a major ESC effect.

The analysis uses a case-control method based on the induced exposure method (Evans, 1986). 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 1. There were 10,475 case vehicles and 41,656 control vehicles in the dataset.

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 1. 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 2.

Table 2. 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) $\text{Odds}_{ESC}\ (\text{Control/Case}) = N_{00}/N_{01}$

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

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

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

Section 3:
RESULTS

The following results show the relative rates of crash involvement for cars with ESC under a variety of different conditions. Vehicles were classified according to the injury severity of the crash in which they were involved. Tables containing the data used in the effectiveness calculations are shown in appendix 2.

Figure 1 shows the distribution of injury severity for all vehicles in the combined case-control groups. 90% involve only minor injuries with fatal accounting for only 1% of vehicles.

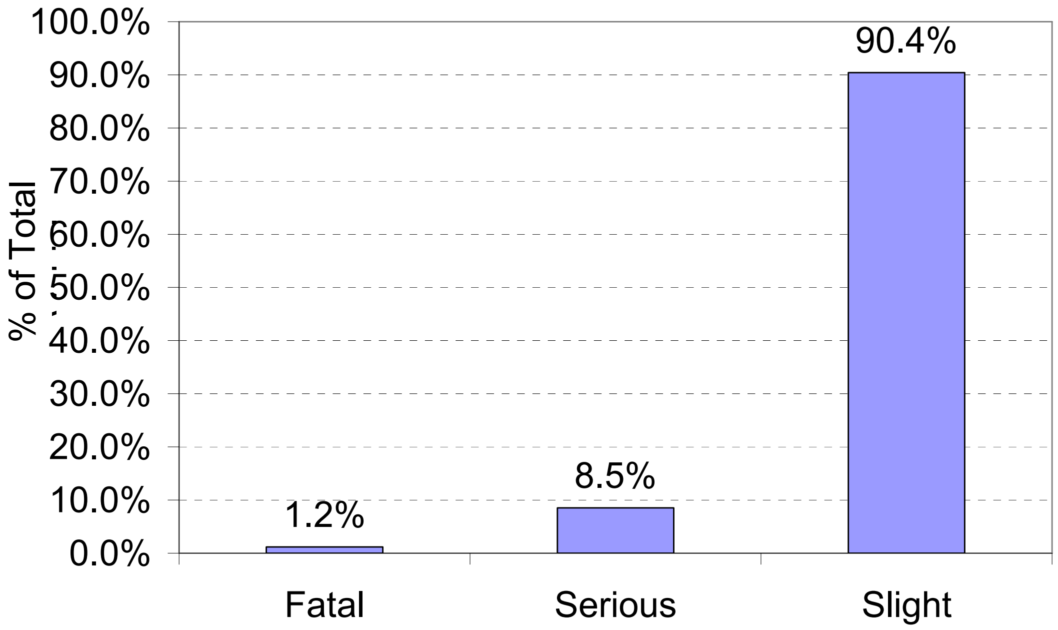

Figure 1. Distribution of Injury Severities

3.1 ESC Effectiveness in all Crash Types

The results in figure 2 below show the effectiveness of ESC for all crash types and all road conditions in crashes from 2002 to 2005. The best estimates are shown for each injury severity level together with 95% confidence limits. Table 3 shows the numbers of matched cases used to calculate effectiveness estimates.

Table 3. Numbers of Cases used to Calculate Overall Effectiveness

Crash Severity	ESC Cars N	Non ESC Cars N
All Injuries	10475	41656
Fatal	110	491
Serious	846	3564
Slight	9519	37601

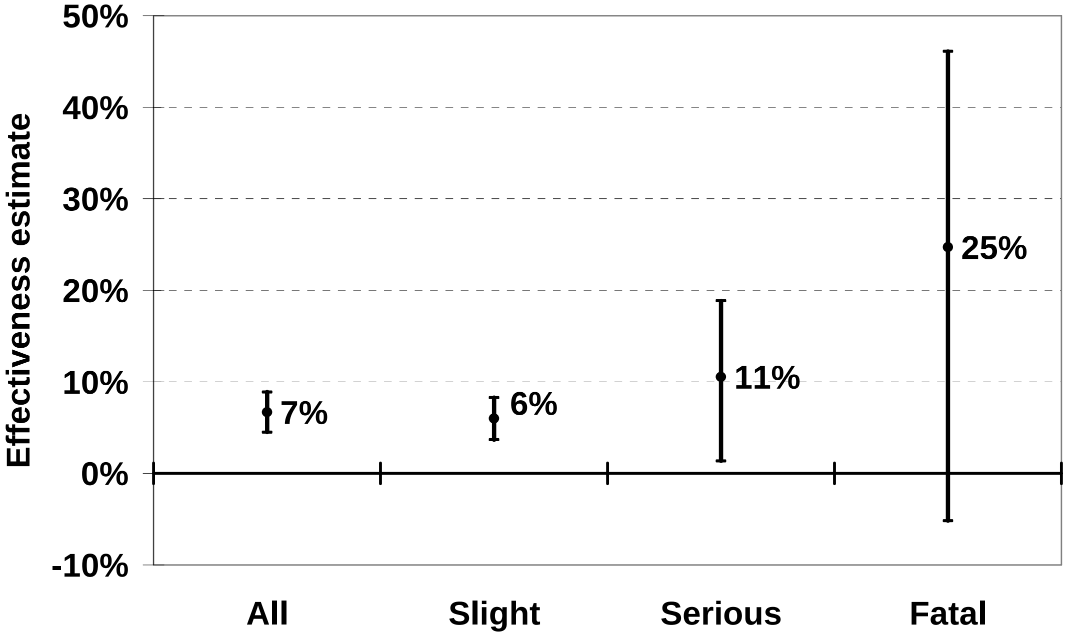

Figure 2. ESC Effectiveness for all Crash Types

For all injury severities the ESC best effectiveness estimate is 7% with a lower confidence interval of 5% and an upper limit of 9%. For fatals, the ESC best effectiveness estimate is 25% with a lower confidence interval of -5% and an upper limit of 46%. For serious crashes, the ESC best effectiveness estimate is 11% with a lower confidence interval of 1% and an upper limit of 19%. For slight crashes the effectiveness is 6% with a lower bound of 4% and a higher bound of 8%.

For all injury severities, slight and serious, none of the confidence intervals cross the axis, indicating that there is a significant difference between crash involvement of ESC equipped and non equipped cars. The larger confidence interval for fatal crashes is because the sample size is smaller than for the other levels of injury outcome.

3.2 Costs of all Crash Types

Table 4 shows the costs of crashes involving cars in 2005. The number of crashes excludes those involving vulnerable road users (cyclists, motorcycles, pedestrians). Cost per accident comes from Highway Economics Note No.1 2005 Valuation of the Benefits of Prevention of Road Accidents and Casualties (Department for Transport 2007). The cost of all crashes involving cars but not involving vulnerable road users was 6.4 billion pounds in 2005. For

each fatal crash there were nearly 100 slight crashes yet the total cost of slight crashes were 0.5 billion pounds less.

Table 4. Total Cost of Crashes involving Cars in 2005

Severity of Crashes Involving Cars in GB (2005)	N	Average Value of Prevention per Crash in UKP	Cost of Crashes in 2005 UKP
Fatal	1,531	1,644,790	2518,173,490
Serious	10,014	188,920	1891,844,880
Slight	105,242	19,250	2025,908,500
Total	116,787		6435,926,870

3.3 Cost Savings of ESC in All Crash Types

Table 5 shows the cost savings and reduction in accident numbers with varying levels of ESC fleet penetration using 2005 crash costs. The best ESC effectiveness estimate is used in each case.

Table 5. Cost and Casualty Savings by Market Penetration

ESC Penetration	Crash Severity	Best Effectiveness	Cost Saving in UKP	Reduction in Crashes (N)
100%	Fatal	25%	629,543,373	383
100%	Serious	11%	208,102,937	1102
100%	Slight	6%	121,554,510	6315
100%	Total		959,200,820	7800
75%	Fatal	25%	472,157,529	287
75%	Serious	11%	156,077,203	826
75%	Slight	6%	91,165,883	4736
75%	Total		719,400,615	5849
50%	Fatal	25%	314,771,686	191
50%	Serious	11%	104,051,468	551
50%	Slight	6%	60,777,255	3157
50%	Total		479,600,409	3899
25%	Fatal	25%	157,385,843	96
25%	Serious	11%	52,025,734	275
25%	Slight	6%	30,388,628	1579
25%	Total		239,800,205	1950
10%	Fatal	25%	62,954,337	38
10%	Serious	11%	20,810,294	110
10%	Slight	6%	12,155,451	631
10%	Total		95,920,082	779

Table 5 shows that with 100% penetration of ESC, total accident cost savings would be 959 million pounds based on 2005 accident figures. At 50% penetration, cost savings are still substantial at almost 500 million pounds. At 10% market penetration the overall saving drops to 95 million pounds. These figures do not, of course consider the cost of ESC fitment to the manufacturer and/or the consumer.

3.4 ESC Effectiveness and Road Surface Conditions

Figure 3 shows the distribution of crashes for all vehicles in the combined case-control groups by road surface condition. Figures 4 – 6 show the distribution of each road condition and the relative crash involvement of ESC cars compared to those without ESC.

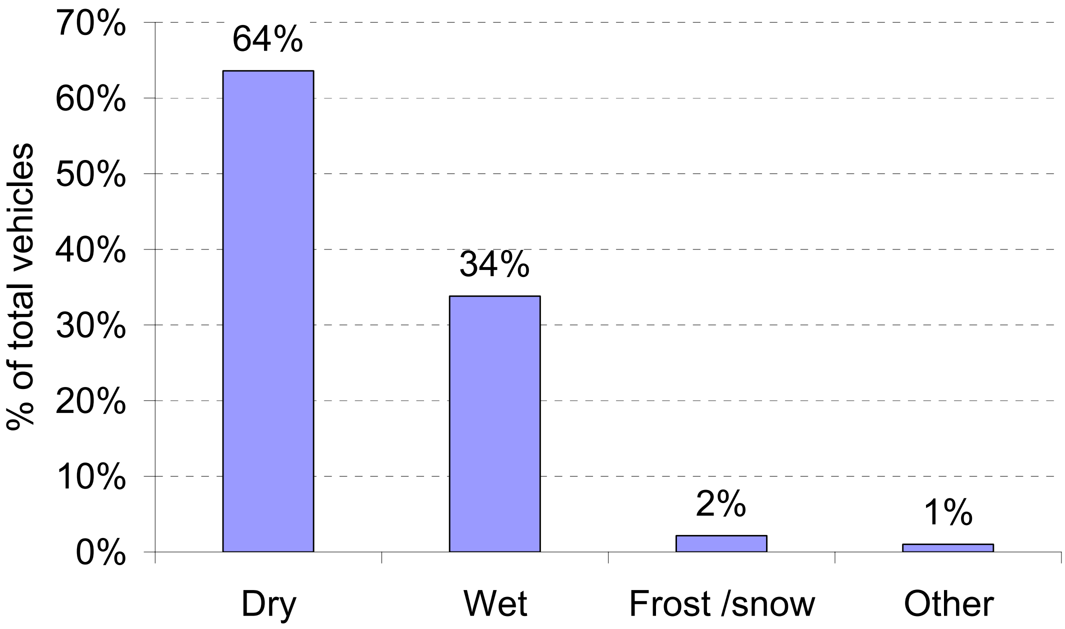

Figure 3. Distribution of Road Surface Conditions

64% of crashes occurred when the road was dry. Overall effectiveness for those conditions was 5% compared to 9% for wet roads and 20% for icy/snowy roads. In terms of serious crashes, ESC appeared to be more beneficial for wet roads (22%) and snowy/icy roads (30%) compared to dry conditions (3%). The value for snowy/icy roads should be viewed with caution however as the error band is wide and negative at the one extreme. In terms of fatal crashes, again there is an indication that ESC is more beneficial in adverse road conditions. Effectiveness was not calculated for fatal crashes in snowy/icy conditions due to low numbers of crashes involving case and control vehicles under those conditions.

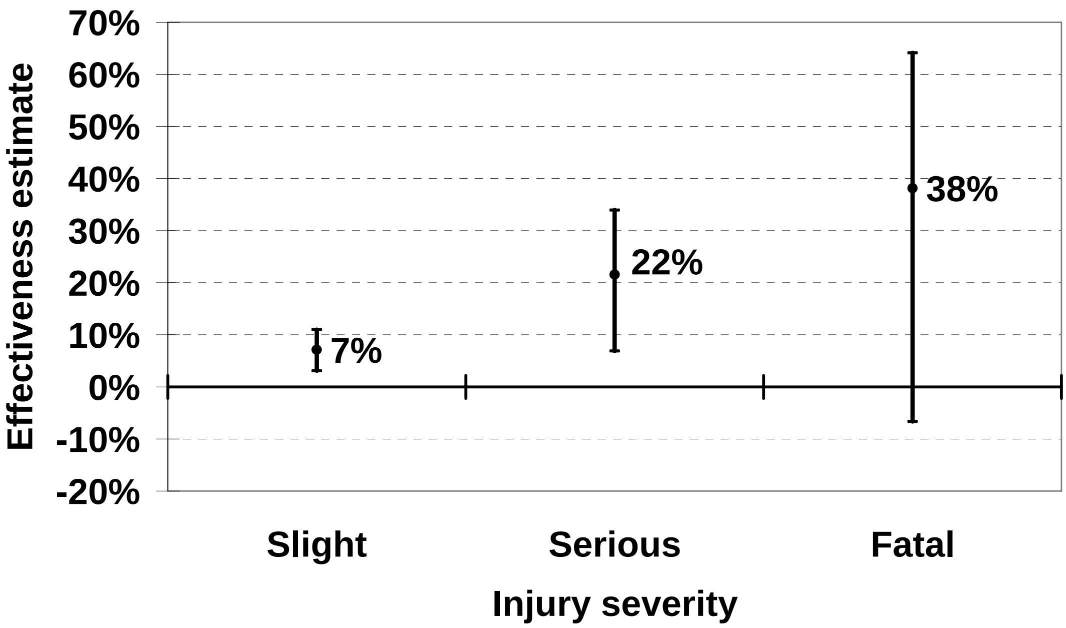

Figure 4. ESC Reduction for Wet Road Surfaces

Figure 5. ESC Reduction for Dry Road Surfaces

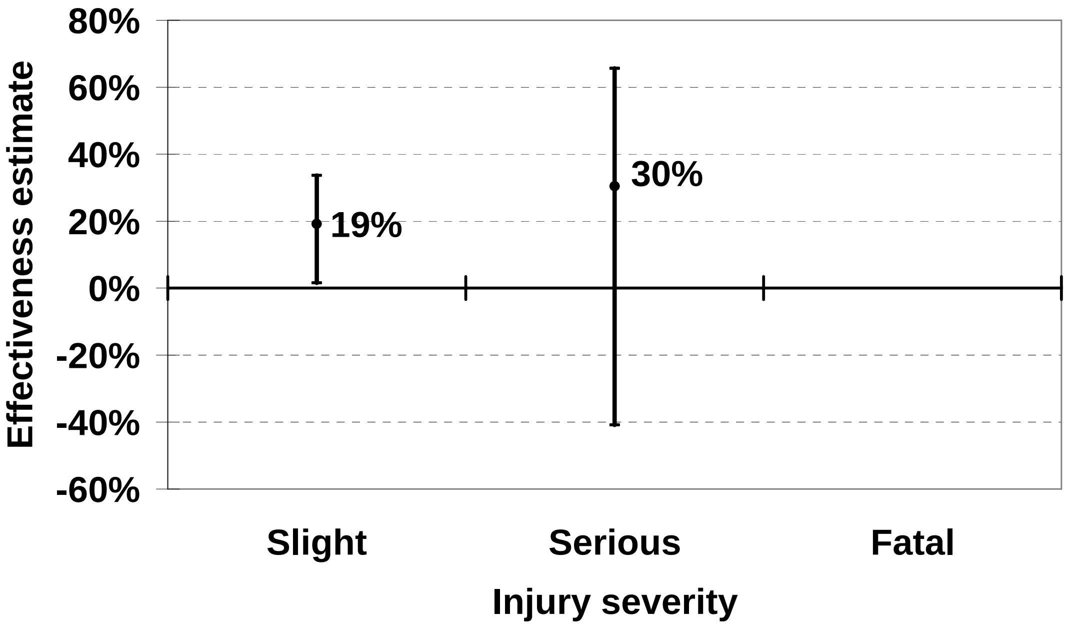

Figure 6. ESC Reduction for Snowy and Icy Road Surfaces

3.5 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.

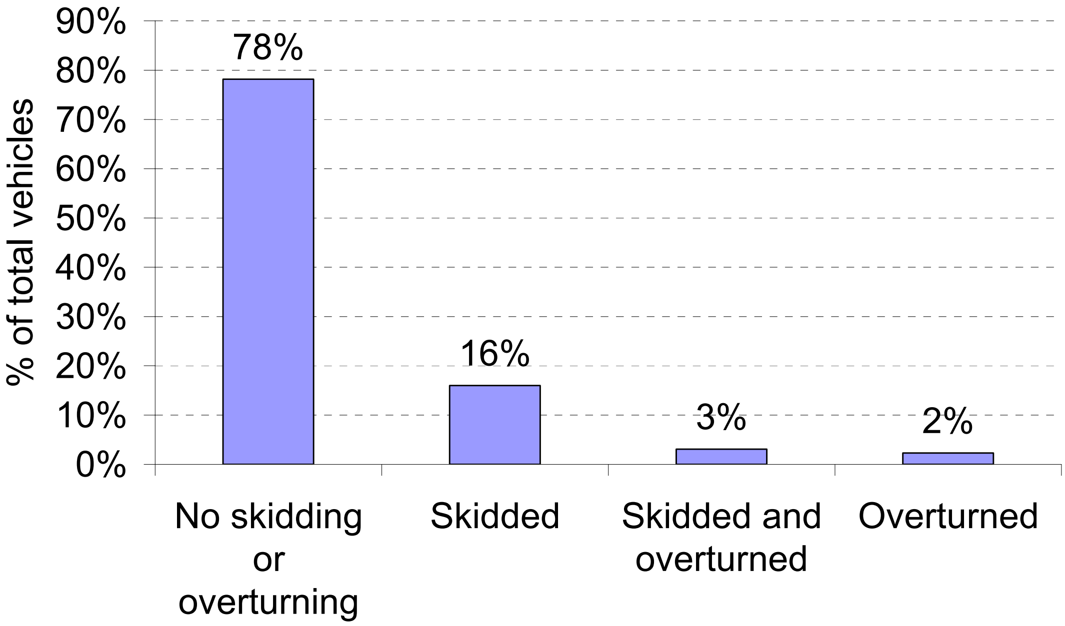

Figure 7. Distribution of Skidding and Overturning

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.

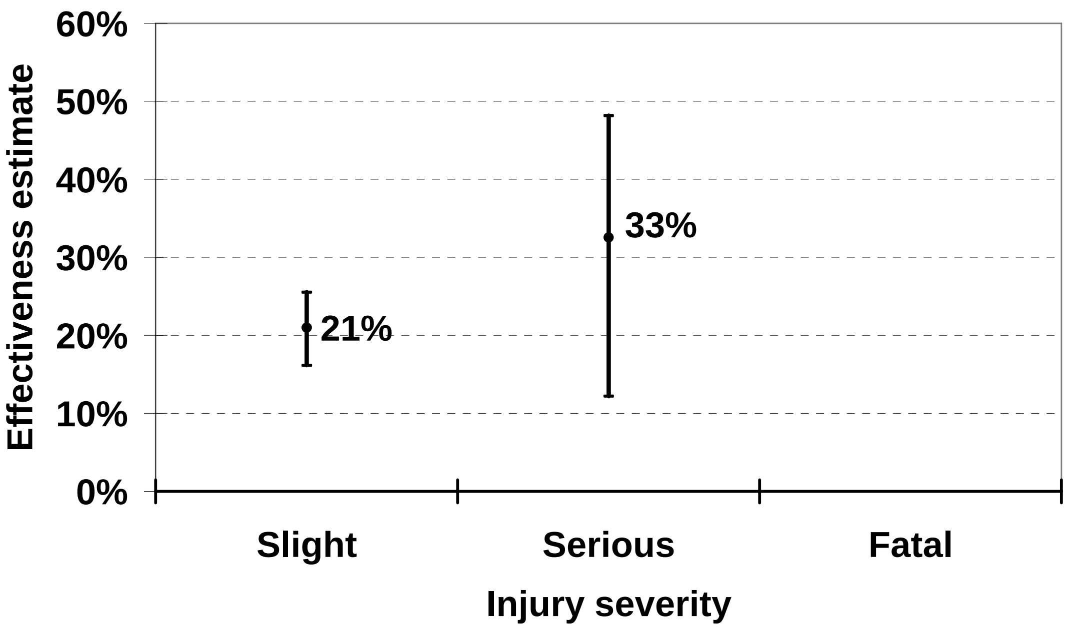

Figure 8. ESC reduction in Skidding Related crashes

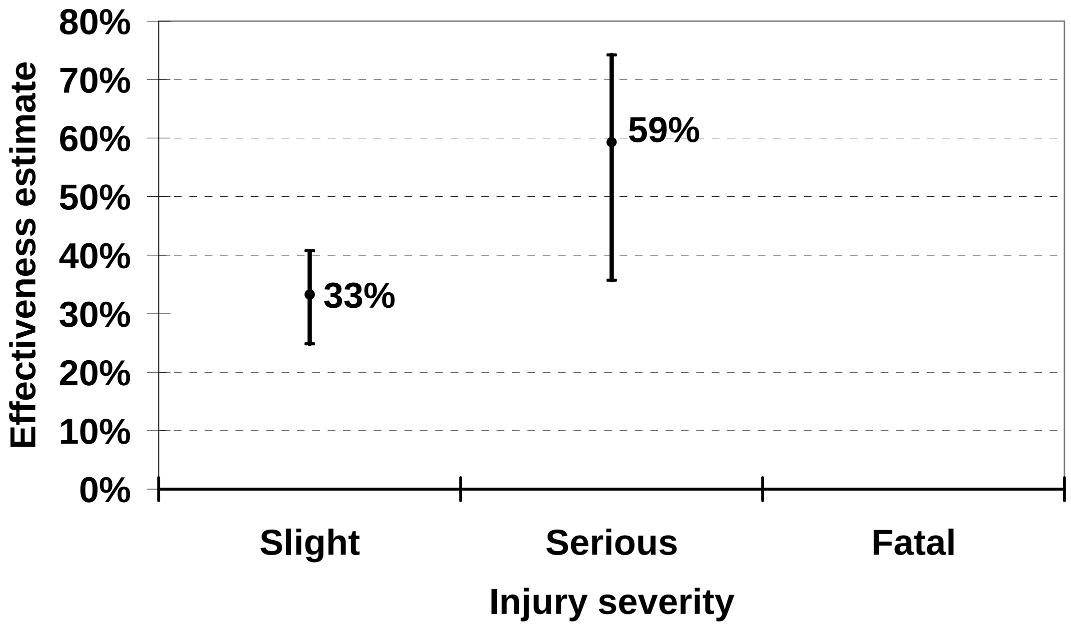

Figure 9. ESC Reduction in Overturning Crashes

3.6 ESC Effectiveness in Single Vehicle Crashes

Single vehicle crashes are those which 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.

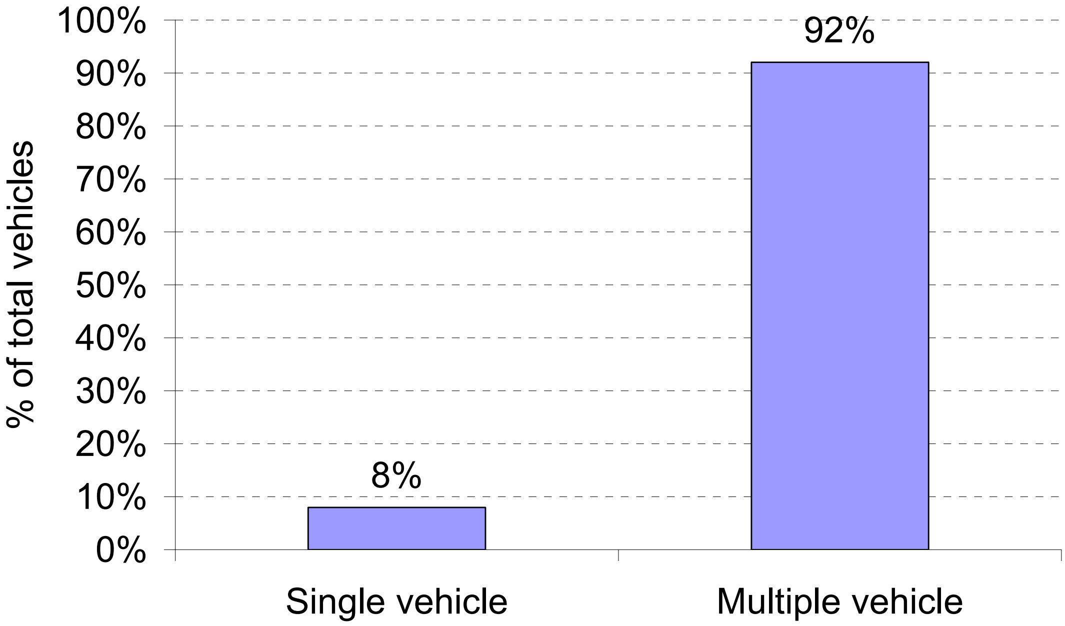

Figure 10. Numbers of Vehicles Involved in Crash

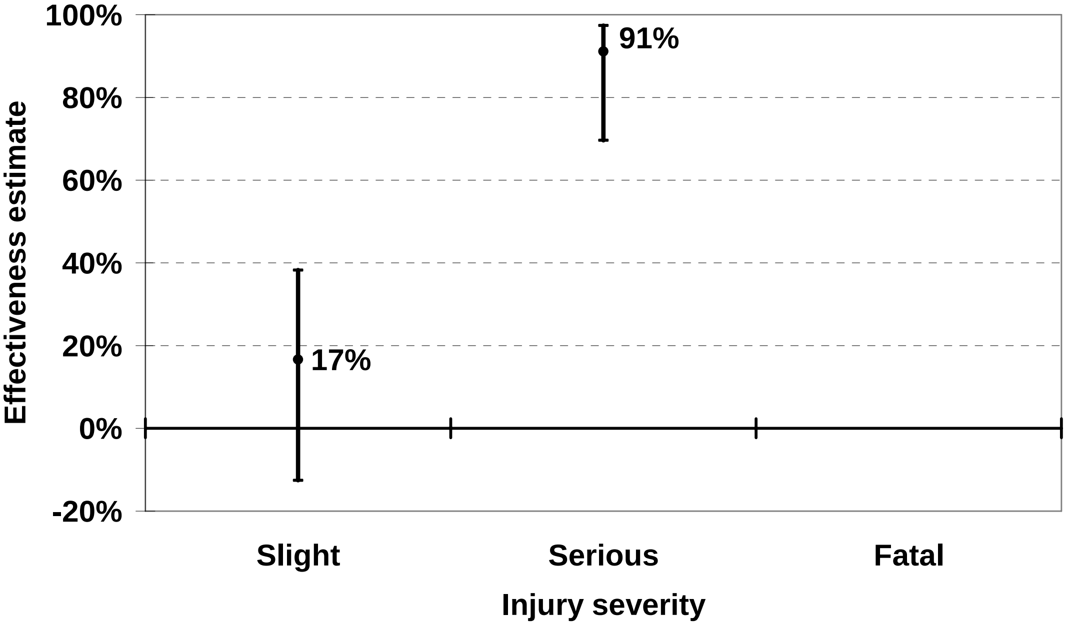

Figure 11. ESC Reduction in Single Vehicle Crashes

3.7 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.

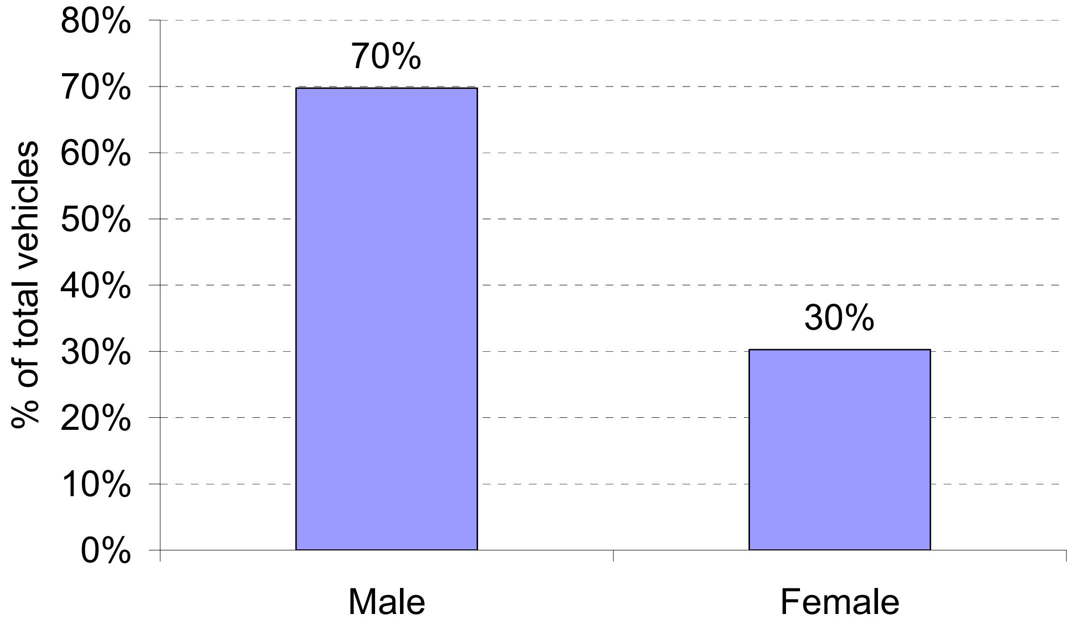

Figure 12. Distribution of Driver Gender

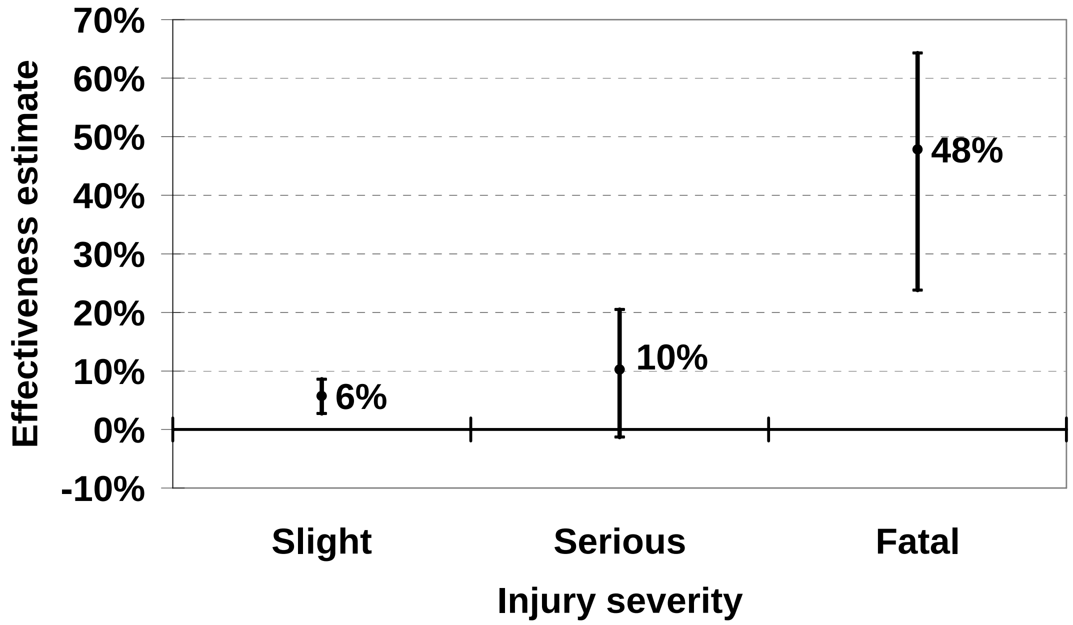

Figure 13. ESC Reduction in Cars with Male Drivers

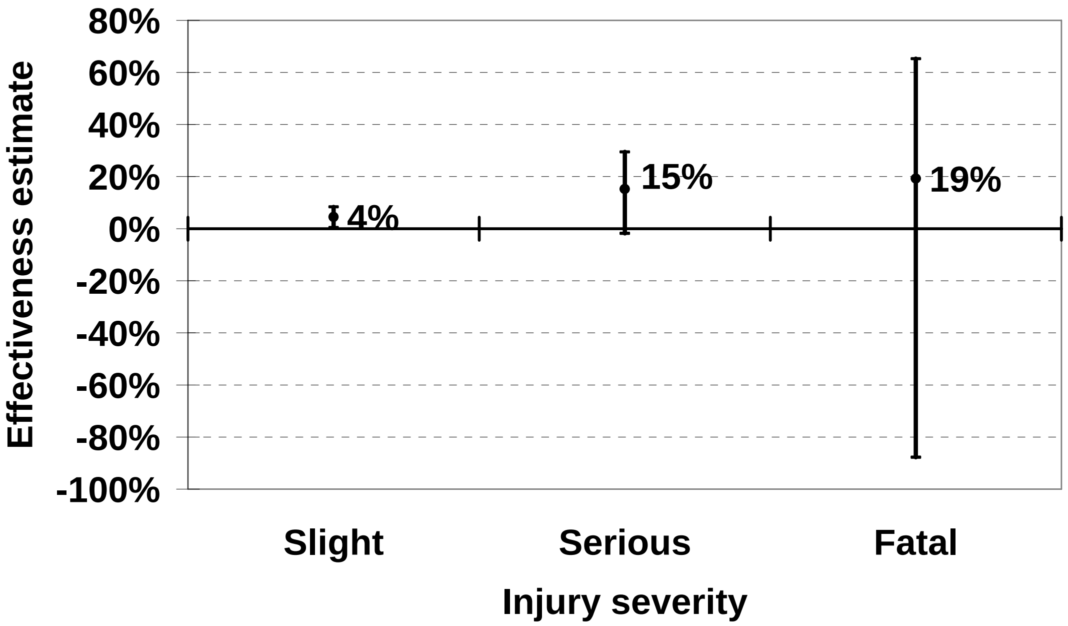

Figure 14. ESC Reduction in Cars with Female Drivers

3.8 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.

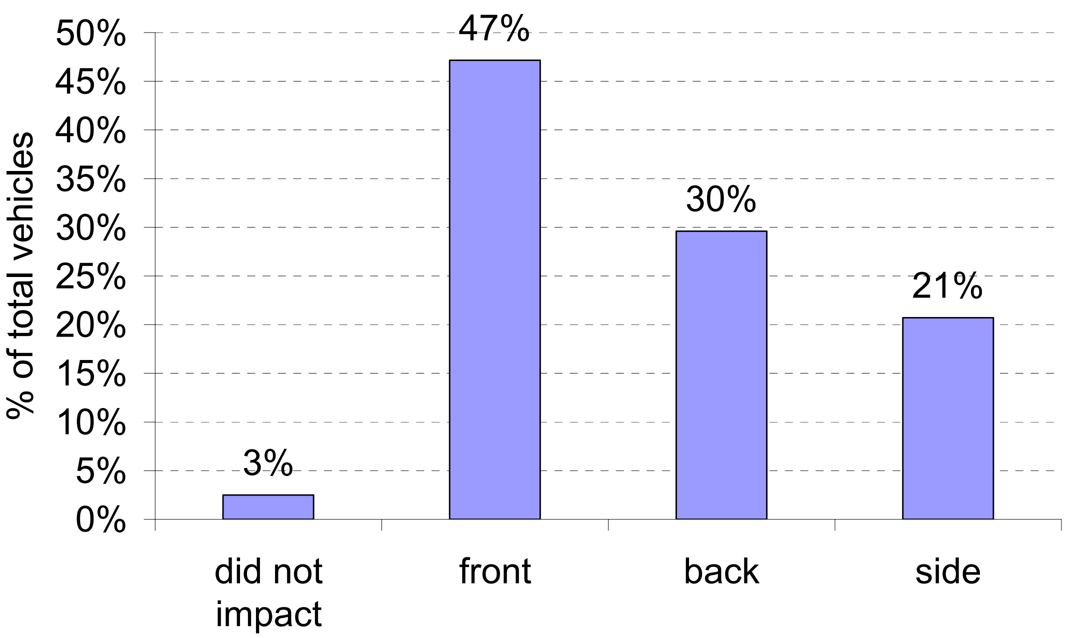

Figure 15. First Point of Impact to Car

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.

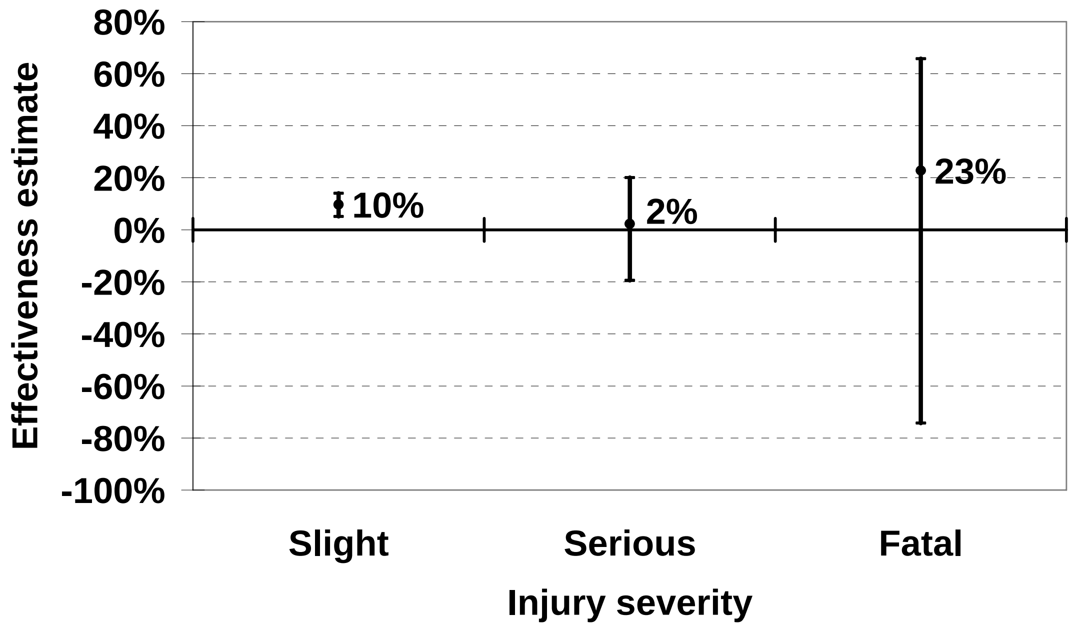

Figure 16. ESC Reduction in Front Collisions

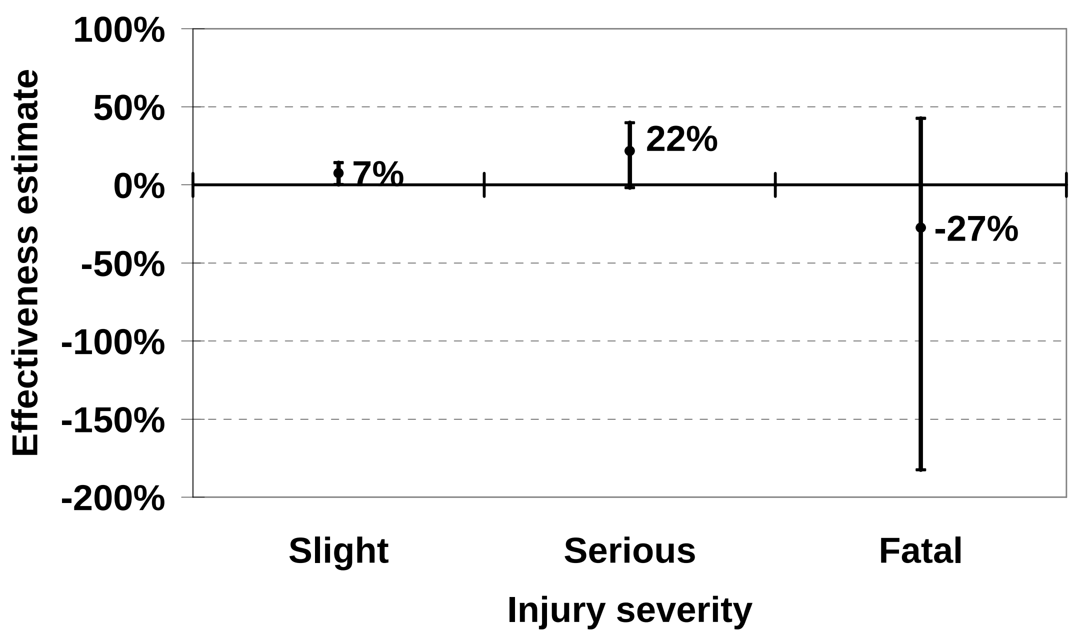

Figure 17. ESC Reduction in Side Collisions

Section 4:
CONCLUSIONS

This report has evaluated the potential 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, driver gender, impact type and single vehicle crashes. In addition, a study of ESC benefits in terms of crash costs and accidents prevented has been undertaken. Table 6 below summarises the effects of ESC. The results are shown without error estimates and a negative value indicates an increase in crash involvement for ESC equipped cars.

Table 6. Summary of ESC Effectiveness

Condition	Effectiveness			
	Slight (%)	Serious (%)	Fatal (%)	All (%)
All Crashes	6	11	25	7
Dry Roads	5	3	17	5
Wet Roads	7	22	38	9
Ice/snow Roads	19	30	-	20
Single vehicle Crashes	17	91	-	27
Male	6	10	48	7
Female	4	15	19	5
Skidding	21	33	-	23
Overturning	33	59	-	36
Front Impacts	10	2	23	10
Side Impacts	7	22	-27	9

The cost savings for varying take-up of ESC are as follows. It should be noted that these are based on 2005 accident figures for Great Britain and all accidents where a car was involved but no vulnerable road user.

Cost for fatalities was 2.5 billion UKP

Cost for serious was 1.9 billion UKP

Cost for slight was 2.0 billion UKP

Total cost for all severities was 6.4 billion UKP

With 100% fitment

629 million UKP saved from fatals (383 crashes less)

208 million UKP saved from serious (1102 crashes less)

121 million UKP saved from slight (6325 crashes less)

959 million UKP saved from all crashes (7800 crashes less)

With 75% fitment

472 million UKP saved from fatals (287 crashes less)

156 million UKP saved from serious (826 crashes less)
91 million UKP saved from slight (4736 crashes less)
719 million UKP saved from all crashes (5849 crashes less)

With 50% fitment
315 million UKP saved from fatals (191 crashes less)
104 million UKP saved from serious (551 crashes less)
60 million UKP saved from slight (3157 crashes less)
480 million UKP saved from all crashes (3899 crashes less)

With 25% fitment
157 million UKP saved from fatals (96 crashes less)
52 million UKP saved from serious (275 crashes less)
30 million UKP saved from slight (1579 crashes less)
240 million UKP saved from all crashes (1950 crashes less)

With 10% fitment
63 million UKP saved from fatals (38 crashes less)
21 million UKP saved from serious (110 crashes less)
12 million UKP saved from slight (631 crashes less)
96 million UKP saved from all crashes (779 crashes less)

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 959 million pounds by preventing some 7800 crashes. Even at a 50% take up the saving amounts to some 480 million pounds. An additional method for calculating cost savings is shown in appendix 4. This method uses assumptions about actual ESC penetration in Britain to 2018.

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 EU 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). Additionally, most of the non-ESC cars in this study would also have been fitted with ABS.

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. Appendix 3 shows that the cars with ESC were generally newer than those without. Nevertheless, the median year of manufacture for the control group was year 2000 with an interquartile range of 1997 – 2002. Generally then, 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 mis-classified, however, Kreiss et al (2005) have shown that the effect of misclassification will be to consistently underestimate the effects of ESC. In that respect, any estimates of ESC effectiveness shown in this study should be viewed as conservative. Crashes involving vulnerable road users were excluded from this analysis for reasons already stated in the methodology. Inclusion of those crashes would have increased the numbers of cars in the case/control group by 15,931. The effect on ESC effectiveness rates would have however been marginal. A decrease of <1% for all crashes, a decrease of <2% for fatal crashes, serious crashes would have remained the same and there would have been a decrease of <1% for slight crashes. Overall, any ESC effectiveness in crashes with VRU's can only support the conservative nature of the results presented in this study.

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

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APPENDIX 1 – Case Vehicles (ESC) and Control Vehicles (Non ESC)

Case Vehicles

ALFA ROMEO	BMW X5	MERCEDES ML350
AUDI A2	BMW Z3	MERCEDES ML55
AUDI A3	BMW Z8	MERCEDES S280
AUDI A4	CITROEN C5	MERCEDES S320
AUDI A6	CITROEN C8	MERCEDES S350
AUDI RS6	CITROEN XSARA	MERCEDES S430
AUDI S3	FIAT PUNTO	MERCEDES S430L
AUDI S8	FIAT STILO	MERCEDES S500
AUDI TT	JAGUAR S-TYPE	MERCEDES S500L
BMW 316	JAGUAR XJ6	MERCEDES S55
BMW 316I	JAGUAR XJ8	MERCEDES S600
BMW 316TI	JAGUAR XJR	MERCEDES SL280
BMW 318	LAMBORGHINI MURCIELAGO	MERCEDES SL320
BMW 318CI	LAND ROVER	MERCEDES SL500
BMW 318I	LEXUS GS300	MERCEDES SL55
BMW 318TI	LEXUS GS430	MERCEDES SLK
BMW 320	LEXUS LS400	MITSUBISHI GALANT
BMW 320CI	JAGUAR XJ6	NISSAN SKYLINE
BMW 320D	LEXUS LS430	PEUGEOT 206
BMW 320I	LEXUS RX300	PEUGEOT 307
BMW 320TD	LEXUS SC430	PEUGEOT 406
BMW 323	MAZDA 6	PEUGEOT 607
BMW 323CI	MAZDA PREMACY	PORSCHE 911
BMW 323I	MAZDA RX-8	PORSCHE CAYENNE
BMW 325	MERCEDES A140	RENAULT ESPACE
BMW 325CI	MERCEDES A160	RENAULT GRAND
BMW 325I	MERCEDES A170	RENAULT LAGUNA
BMW 328	MERCEDES A190	RENAULT VEL
BMW 328I	MERCEDES A210	SEAT LEON
BMW 330CI	MERCEDES C180	SKODA OCTAVIA
BMW 330D	MERCEDES C200	SKODA SUPERB
BMW 330I	MERCEDES C220	SMART CITY
BMW 520I	MERCEDES C230	TOYOTA AVENSIS
BMW 525	MERCEDES C240	TOYOTA COROLLA
BMW 525D	MERCEDES C250	VAUXHALL ASTRA
BMW 525I	MERCEDES C320	VAUXHALL SIGNUM
BMW 528I	MERCEDES C43	VAUXHALL VECTRA
BMW 530D	MERCEDES CL500	VOLKSWAGEN BEETLE
BMW 530I	MERCEDES CL55	VOLKSWAGEN BORA
BMW 535I	MERCEDES CLK	VOLKSWAGEN GOLF
BMW 540I	MERCEDES CLK430	VOLKSWAGEN PASSAT
BMW 728I	MERCEDES CLK55	VOLKSWAGEN TOUAREG
BMW 730	MERCEDES E200	VOLVO C70
BMW 735I	MERCEDES E220	VOLVO S40
BMW 740	MERCEDES E240	VOLVO S60
BMW 750I	MERCEDES E270	VOLVO S80
BMW 760	MERCEDES E280	VOLVO V40
BMW 840	MERCEDES E320	VOLVO V70
BMW 850	MERCEDES E430	VOLVO XC
BMW M	MERCEDES E55	VOLVO XC70
BMW M3	MERCEDES ML	
BMW M5	MERCEDES ML270	

Control Vehicles

ALFA ROMEO	LAMBORGHINI DIABLO	
AUDI A2	LAND ROVER	MERCEDES S55
AUDI A3	LEXUS GS300	MERCEDES S600
AUDI A4	LEXUS GS430	MERCEDES SL
AUDI A6	LEXUS RX300	MERCEDES SL280
AUDI A8	LEXUS SC430	MERCEDES SL320
AUDI RS6	MAZDA 6	MERCEDES SL500
AUDI S3	MAZDA PREMACY	MERCEDES SL55
AUDI S4	MERCEDES A140	MERCEDES SL600
AUDI S6	MERCEDES A160	MERCEDES SLK
AUDI S8	MERCEDES C-230	MERCEDES SLK200
AUDI TT	MERCEDES C-36	MITSUBISHI GALANT
BMW 316	MERCEDES C180	NISSAN PRIMERA
BMW 318	MERCEDES C200	NISSAN SKYLINE
BMW 320	MERCEDES C220	PEUGEOT 206
BMW 323	MERCEDES C230	PEUGEOT 307
BMW 325	MERCEDES C250	PEUGEOT 406
BMW 328	MERCEDES C270	PEUGEOT 607
BMW 330	MERCEDES C280	PORSCHE 911
BMW 518	MERCEDES C320	PORSCHE CAYENNE
BMW 520	MERCEDES C36	RENAULT AVANTIME
BMW 525	MERCEDES CL420	RENAULT ESPACE
BMW 528	MERCEDES CL500	RENAULT LAGUNA
BMW 530	MERCEDES CL55	SEAT LEON
BMW 535	MERCEDES CL600	SKODA OCTAVIA
BMW 540	MERCEDES CLK	SKODA SUPERB
BMW 728	MERCEDES CLK200	SMART CITY
BMW 730	MERCEDES CLK230	TOYOTA AVENSIS
BMW 735	MERCEDES CLK270	TOYOTA CAMRY
BMW 740	MERCEDES CLK320	TOYOTA COROLLA
BMW 840	MERCEDES CLK430	TOYOTA LANDCRUISER
BMW 850	MERCEDES CLK55	VAUXHALL ASTRA
BMW M	MERCEDES E200	VAUXHALL SIGNUM
BMW M3	MERCEDES E220	VAUXHALL VECTRA
BMW M5	MERCEDES E230	VOLKSWAGEN BEETLE
BMW M535I	MERCEDES E240	VOLKSWAGEN BORA
BMW X5	MERCEDES E250	VOLKSWAGEN GOLF
BMW Z3	MERCEDES E250D	VOLKSWAGEN PASSAT
CITROEN C5	MERCEDES E270	VOLKSWAGEN TOUAREG
CITROEN C8	MERCEDES E280	VOLVO C70
CITROEN XSARA	MERCEDES E36	VOLVO S40
FIAT PUNTO	MERCEDES E430	VOLVO S60
FIAT STILO	MERCEDES E55	VOLVO S80
JAGUAR S-TYPE	MERCEDES ML	VOLVO V40
JAGUAR XJ-S	MERCEDES ML270	VOLVO V70
JAGUAR XJ	MERCEDES ML350	VOLVO XC
JAGUAR XJ12	MERCEDES S280	VOLVO XC70
JAGUAR XJ6	MERCEDES S320	
JAGUAR XJ8	MERCEDES S320L	
JAGUAR XJR	MERCEDES S350	
JAGUAR XJS	MERCEDES S420	
LAMBORGHINI	MERCEDES S500	

APPENDIX 2 – Case and Control Contingency Tables

All Crash Types – All Injuries

	Control Manoeuvre (assumed no ESC effect)	Other Manoeuvre (ESC effect possible)	Total
Control vehicle (no ESC)	12531	29125	41656
Case vehicle (ESC)	3307	7168	10475
Total	15838	36293	52131

All Crash Types – Fatal

	Control Manoeuvre (assumed no ESC effect)	Other Manoeuvre (ESC effect possible)	Total
Control vehicle (no ESC)	45	446	491
Case vehicle (ESC)	13	97	110
Total	58	543	601

All Crash Types – Serious

	Control Manoeuvre (assumed no ESC effect)	Other Manoeuvre (ESC effect possible)	Total
Control vehicle (no ESC)	627	2937	3564
Case vehicle (ESC)	163	683	846
Total	790	3620	4410

All Crash Types – Slight

	Control Manoeuvre (assumed no ESC effect)	Other Manoeuvre (ESC effect possible)	Total
Control vehicle (no ESC)	11859	25742	37601
Case vehicle (ESC)	3131	6388	9519
Total	14990	32130	47120

Wet Road – All Injuries

	Control Manoeuvre (assumed no ESC effect)	Other Manoeuvre (ESC effect possible)	Total
Control vehicle (no ESC)	3997	10061	14058
Case vehicle (ESC)	1080	2475	3555
Total	5077	12536	17613

Wet Road – Fatal

	Control Manoeuvre (assumed no ESC effect)	Other Manoeuvre (ESC effect possible)	Total
Control vehicle (no ESC)	15	194	209
Case vehicle (ESC)	5	40	45
Total	20	234	254

Wet Road – Serious

	Control Manoeuvre (assumed no ESC effect)	Other Manoeuvre (ESC effect possible)	Total
Control vehicle (no ESC)	185	1143	1328
Case vehicle (ESC)	52	252	304
Total	237	1395	1632

Wet Road – Slight

	Control Manoeuvre (assumed no ESC effect)	Other Manoeuvre (ESC effect possible)	Total
Control vehicle (no ESC)	3797	8724	12521
Case vehicle (ESC)	1023	2183	3206
Total	4820	10907	15727

Dry Road – All Injuries

	Control Manoeuvre (assumed no ESC effect)	Other Manoeuvre (ESC effect possible)	Total
Control vehicle (no ESC)	8329	18123	26452
Case vehicle (ESC)	2174	4491	6665
Total	10503	22614	33117

Dry Road – Fatal

	Control Manoeuvre (assumed no ESC effect)	Other Manoeuvre (ESC effect possible)	Total
Control vehicle (no ESC)	30	245	275
Case vehicle (ESC)	8	54	62
Total	38	299	337

Dry Road – Serious

	Control Manoeuvre (assumed no ESC effect)	Other Manoeuvre (ESC effect possible)	Total
Control vehicle (no ESC)	430	1674	2104
Case vehicle (ESC)	108	408	516
Total	538	2082	2620

Dry Road – Slight

	Control Manoeuvre (assumed no ESC effect)	Other Manoeuvre (ESC effect possible)	Total
Control vehicle (no ESC)	7869	16204	24073
Case vehicle (ESC)	2058	4029	6087
Total	9927	20233	30160

Snowy/Icy Road – All Injuries

	Control Manoeuvre (assumed no ESC effect)	Other Manoeuvre (ESC effect possible)	Total
Control vehicle (no ESC)	162	743	905
Case vehicle (ESC)	45	165	210
Total	207	908	1115

Snowy/Icy Road – Fatal

	Control Manoeuvre (assumed no ESC effect)	Other Manoeuvre (ESC effect possible)	Total
Control vehicle (no ESC)		7	7
Case vehicle (ESC)		2	2
Total		9	9

Snowy/Icy Road – Serious

	Control Manoeuvre (assumed no ESC effect)	Other Manoeuvre (ESC effect possible)	Total
Control vehicle (no ESC)	10	91	101
Case vehicle (ESC)	3	19	22
Total	13	110	123

Snowy/Icy Road – Slight

	Control Manoeuvre (assumed no ESC effect)	Other Manoeuvre (ESC effect possible)	Total
Control vehicle (no ESC)	152	645	797
Case vehicle (ESC)	42	144	186
Total	194	789	983

Skidding – All Injuries

	Control Manoeuvre (assumed no ESC effect)	Other Manoeuvre (ESC effect possible)	Total
Control vehicle (no ESC)	1851	5638	7489
Case vehicle (ESC)	557	1305	1862
Total	2408	6943	9351

Skidding – Fatal

	Control Manoeuvre (assumed no ESC effect)	Other Manoeuvre (ESC effect possible)	Total
Control vehicle (no ESC)	9	102	111
Case vehicle (ESC)	1	17	18
Total	10	119	129

Skidding – Serious

	Control Manoeuvre (assumed no ESC effect)	Other Manoeuvre (ESC effect possible)	Total
Control vehicle (no ESC)	74	747	821
Case vehicle (ESC)	21	143	164
Total	95	890	985

Skidding – Slight

	Control Manoeuvre (assumed no ESC effect)	Other Manoeuvre (ESC effect possible)	Total
Control vehicle (no ESC)	1768	4789	6557
Case vehicle (ESC)	535	1145	1680
Total	2303	5934	8237

Overturning – All Injuries

	Control Manoeuvre (assumed no ESC effect)	Other Manoeuvre (ESC effect possible)	Total
Control vehicle (no ESC)	390	1713	2103
Case vehicle (ESC)	138	389	527
Total	528	2102	2630

Overturning – Fatal

	Control Manoeuvre (assumed no ESC effect)	Other Manoeuvre (ESC effect possible)	Total
Control vehicle (no ESC)	3	35	38
Case vehicle (ESC)	0	5	5
Total	3	40	43

Overturning – Serious

	Control Manoeuvre (assumed no ESC effect)	Other Manoeuvre (ESC effect possible)	Total
Control vehicle (no ESC)	16	280	296
Case vehicle (ESC)	8	57	65
Total	24	337	361

Overturning – Slight

	Control Manoeuvre (assumed no ESC effect)	Other Manoeuvre (ESC effect possible)	Total
Control vehicle (no ESC)	371	1398	1769
Case vehicle (ESC)	130	327	457
Total	501	1725	2226

Single Vehicle – All Injuries

	Control Manoeuvre (assumed no ESC effect)	Other Manoeuvre (ESC effect possible)	Total
Control vehicle (no ESC)	62	3423	3485
Case vehicle (ESC)	16	644	660
Total	78	4067	4145

Single Vehicle – Fatal

	Control Manoeuvre (assumed no ESC effect)	Other Manoeuvre (ESC effect possible)	Total
Control vehicle (no ESC)		90	90
Case vehicle (ESC)		15	15
Total		105	105

Single Vehicle – Serious

	Control Manoeuvre (assumed no ESC effect)	Other Manoeuvre (ESC effect possible)	Total
Control vehicle (no ESC)	1	636	637
Case vehicle (ESC)	2	113	115
Total	3	749	752

Single Vehicle – Slight

	Control Manoeuvre (assumed no ESC effect)	Other Manoeuvre (ESC effect possible)	Total
Control vehicle (no ESC)	61	2697	2758
Case vehicle (ESC)	14	516	530
Total	75	3213	3288

Male – All Injuries

	Control Manoeuvre (assumed no ESC effect)	Other Manoeuvre (ESC effect possible)	Total
Control vehicle (no ESC)	8259	20532	28791
Case vehicle (ESC)	1996	4632	6628
Total	10255	25164	35419

Male – Fatal

	Control Manoeuvre (assumed no ESC effect)	Other Manoeuvre (ESC effect possible)	Total
Control vehicle (no ESC)	27	367	394
Case vehicle (ESC)	11	78	89
Total	38	445	483

Male – Serious

	Control Manoeuvre (assumed no ESC effect)	Other Manoeuvre (ESC effect possible)	Total
Control vehicle (no ESC)	434	2247	2681
Case vehicle (ESC)	102	474	576
Total	536	2721	3257

Male – Slight

	Control Manoeuvre (assumed no ESC effect)	Other Manoeuvre (ESC effect possible)	Total
Control vehicle (no ESC)	7798	17918	25716
Case vehicle (ESC)	1883	4080	5963
Total	9681	21998	31679

Female – All Injuries

	Control Manoeuvre (assumed no ESC effect)	Other Manoeuvre (ESC effect possible)	Total
Control vehicle (no ESC)	3747	8056	11803
Case vehicle (ESC)	1175	2396	3571
Total	4922	10452	15374

Female – Fatal

	Control Manoeuvre (assumed no ESC effect)	Other Manoeuvre (ESC effect possible)	Total
Control vehicle (no ESC)	7	78	85
Case vehicle (ESC)	2	18	20
Total	9	96	105

Female – Serious

	Control Manoeuvre (assumed no ESC effect)	Other Manoeuvre (ESC effect possible)	Total
Control vehicle (no ESC)	143	658	801
Case vehicle (ESC)	50	195	245
Total	193	853	1046

Female – Slight

	Control Manoeuvre (assumed no ESC effect)	Other Manoeuvre (ESC effect possible)	Total
Control vehicle (no ESC)	3597	7320	10917
Case vehicle (ESC)	1123	2183	3306
Total	4720	9503	14223

Frontal Crashes – All Injuries

	Control Manoeuvre (assumed no ESC effect)	Other Manoeuvre (ESC effect possible)	Total
Control vehicle (no ESC)	2386	17228	19614
Case vehicle (ESC)	638	4164	4802
Total	3024	21392	24416

Frontal Crashes – Fatal

	Control Manoeuvre (assumed no ESC effect)	Other Manoeuvre (ESC effect possible)	Total
Control vehicle (no ESC)	7	299	306
Case vehicle (ESC)	2	66	68
Total	9	365	374

Frontal Crashes – Serious

	Control Manoeuvre (assumed no ESC effect)	Other Manoeuvre (ESC effect possible)	Total
Control vehicle (no ESC)	136	1923	2059
Case vehicle (ESC)	33	456	489
Total	169	2379	2548

Frontal Crashes – Slight

	Control Manoeuvre (assumed no ESC effect)	Other Manoeuvre (ESC effect possible)	Total
Control vehicle (no ESC)	2243	15006	17249
Case vehicle (ESC)	603	3642	4245
Total	2846	18648	21494

Side Crashes – All Injuries

	Control Manoeuvre (assumed no ESC effect)	Other Manoeuvre (ESC effect possible)	Total
Control vehicle (no ESC)	1028	7542	8570
Case vehicle (ESC)	279	1872	2151
Total	1307	9414	10721

Side Crashes – Fatal

	Control Manoeuvre (assumed no ESC effect)	Other Manoeuvre (ESC effect possible)	Total
Control vehicle (no ESC)	12	113	125
Case vehicle (ESC)	2	24	26
Total	14	137	151

Side Crashes – Serious

	Control Manoeuvre (assumed no ESC effect)	Other Manoeuvre (ESC effect possible)	Total
Control vehicle (no ESC)	73	719	792
Case vehicle (ESC)	21	162	183
Total	94	881	975

Side Crashes – Slight

	Control Manoeuvre (assumed no ESC effect)	Other Manoeuvre (ESC effect possible)	Total
Control vehicle (no ESC)	943	6710	7653
Case vehicle (ESC)	256	1686	1942
Total	1199	8396	9595

APPENDIX 3 – Year of Manufacture for Case Vehicles (ESC) and Control Vehicles (Non ESC)

	Year of Manufacture		
Vehicle Type	25^{th} %'ile	50^{th} %'ile	75^{th} %'ile
Control Vehicles (non-ESC)	1997	2000	2002
Case Vehicles (ESC)	2001	2002	2003

APPENDIX 4 - Cost Savings of ESC based on Fleet Penetration

Fleet Penetration

This additional method for calculating cost savings uses assumptions about actual ESC fleet penetration to 2018 in Britain. It assumes no cars with ESC in the vehicle parc until 2008 when all new cars are required to be fitted with ESC. It also assumes that the total number of cars in the UK parc remains constant up to 2018. Table I shows how all cars in the UK could be equipped with ESC by 2018 given new car registrations of 2,500, 000 per year and a constant total of 26,000,000 in the car parc.

Table I: Fleet Penetration of ESC Equipped Cars

Year	Cumulative Total of ESC Cars	Total Cars in Fleet	ESC Cars as % of Total Cars in Fleet
2005	0	26,000,000	0%
2006	0	26,000,000	0%
2007	0	26,000,000	0%
2008	2,500,000	26,000,000	10%
2009	5,000,000	26,000,000	19%
2010	7,500,000	26,000,000	29%
2011	10,000,000	26,000,000	38%
2012	12,500,000	26,000,000	48%
2013	15,000,000	26,000,000	58%
2014	17,500,000	26,000,000	67%
2015	20,000,000	26,000,000	77%
2016	22,500,000	26,000,000	87%
2017	25,000,000	26,000,000	96%
2018	26,000,000	26,000,000	100%

Normal Reduction in Car Occupant Casualties

Table II below shows the normal reduction in car occupant casualties based on the average decline year on year from the 1994-98 average to 2005. The assumption is that the average decline is linear and amounts to 0.5% for fatalities, 4% for serious and 0.9% for slight casualties.

Table II: Normal Reduction in Car Occupant Casualties without ESC

	Casualty Severity		
Year	Slight	Serious	Fatal
2005	163,685	12,942	1675
2006	162212	12424	1667
2007	160752	11927	1658
2008	159305	11450	1650
2009	157871	10992	1642
2010	156451	10553	1634
2011	155043	10130	1625
2012	153647	9725	1617
2013	152264	9336	1609
2014	150894	8963	1601
2015	149536	8604	1593
2016	148190	8260	1585
2017	146856	7930	1577
2018	145535	7613	1569

Casualty Reduction due to ESC

The reduction in numbers of casualties with increasing numbers of ESC cars is calculated as follows: The number of casualties of a given severity resulting from normal reduction is found for a particular year. A percentage of these are taken equating to the ESC fleet penetration percentage for that year. Then a percentage of that is taken relating to the ESC effectiveness for that particular casualty severity. This gives the numbers of casualties that would be reduced in each severity group in a given year. Table III shows the casualty reduction due to ESC by year. ESC effectiveness is given as those values calculated in the main analysis of this report. 25% for fatal, 11% for serious and 6% for slight crashes.

Table III: Casualty Reduction due to ESC by Year

	Casualty Severity		
Year	Slight	Serious	Fatal
2005	0	0	0
2006	0	0	0
2007	0	0	0
2008	919	116	39
2009	1822	222	78
2010	2708	320	116
2011	3578	409	154
2012	4432	491	192
2013	5271	566	229
2014	6094	633	266
2015	6902	695	303
2016	7694	751	339
2017	8472	801	375
2018	8732	799	388

Cost Savings due to ESC

Savings due to ESC penetration in the car fleet were calculated using the Department for Transport values of injury prevention per casualty (Highways Economics Notes No. 1: 2005) multiplied by the numbers of casualties saved. The results are shown in table IV.

Table IV: Savings due to ESC

Year	Slight Savings (£)	Serious Savings (£)	Fatal Savings (£)	Total Savings (£m)
2005	-	-	-	-
2006	-	-	-	-
2007	-	-	-	-
2008	11,368,874	18,552,053	55,966,818	86
2009	22,533,108	35,619,941	111,373,968	170
2010	33,495,466	51,292,715	166,225,647	251
2011	44,258,675	65,654,676	220,526,024	330
2012	54,825,434	78,785,611	274,279,243	408
2013	65,198,406	90,761,024	327,489,416	483
2014	75,380,224	101,652,347	380,160,630	557
2015	85,373,488	111,527,146	432,296,945	629
2016	95,180,767	120,449,318	483,902,393	700
2017	104,804,601	128,479,272	534,980,979	768
2018	108,015,814	128,273,705	553,598,317	790