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Evaluation Note

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PRELIMINARY RESULTS ANALYZING THE EFFECTIVENESS OF ELECTRONIC STABILITY CONTROL (ESC) SYSTEMS

Jennifer N. Dang

Automotive braking technologies have evolved from very simple systems (i.e., block brakes) to more sophisticated systems (i.e., cable-operated four-wheel brakes, hydraulic four-wheel brakes, drum brakes, disc brakes with front-rear split, etc.). Today, drivers rely on much more technical systems to help them not only to decelerate and accelerate but also to stabilize their vehicles while in motion. Antilock Brake Systems (ABS) are the first of a series of three braking technology developments. They are four-wheel systems that prevent wheel lock-up by automatically modulating the brake pressure when the driver makes an emergency stop. Traction Control Systems (TCS) are the second technology. They deal specifically with front-to-back loss of friction between the vehicle's tires and the road surface during *acceleration*. Electronic Stability Control (ESC) systems are another breakthrough technology evolving from and incorporating the first two technologies – ABS and TCS. They are stability enhancement systems designed to improve vehicles' lateral stability by electronically detecting and automatically assisting drivers in dangerous situations (e.g. understeer and oversteer) and under unfavorable conditions (rain, snow, sleet, ice). ESC systems have sensors that monitor the speed of each wheel, the steering wheel angle, and the overall yaw rate and lateral acceleration of the vehicle. Data from the sensors are used to compare a driver's intended course with the vehicle's actual movement to detect when a driver is about to lose control of a vehicle and automatically intervene in split seconds by applying the brakes to individual wheels and possibly reducing engine torque to provide stability and help the driver stay on course. For example, if a system detects that the rear wheels have begun to slide to the right and the vehicle is yawing counter-clockwise, it may momentarily apply the brake to the right front wheel, imparting a clockwise spin to counteract the yaw and stabilize the vehicle. It may then slow down the vehicle to a speed more appropriate for conditions. This technology appears to provide safety benefits by reducing the number of crashes due to driver error and loss of control, because it has the potential to anticipate situations leading up to some crashes before they occur and has the capability in some cases to automatically intervene to prevent them. The potential benefit should be primarily a reduction of single vehicle crashes that involve losing control and running off the road. These crashes include rollovers and collisions with fixed objects.

Sales of vehicles with ESC are increasing. In model year 2003, 7.4 percent of the light vehicle fleet were sold with an ESC system.

NHTSA is in the process of statistically evaluating the effectiveness of ESC in reducing *single vehicle crashes* in various domestic and imported cars and SUVs. At this point the agency has analyzed data from model years 1997 to 2002, in make models where ESC was introduced in those years. The agency is also looking at single- and multi-vehicle *crash rates* per 100,000 registration years to ensure that any reduction in single vehicle crashes is not offset by an increase (if any) in multi-vehicle crashes.

Approach The study at this point consists of a series of analyses of crash data from currently available State and FARS databases. Crash data from calendar years 1997 to 2002 from 5 States (Florida, Illinois, Maryland, Missouri, Utah) were used in the analyses because these are the States that consistently have a high percentage of Vehicle Identification Number (VIN) information in their data files. The effectiveness of ESC in reducing <u>fatal</u> single vehicle crashes was also evaluated by analyzing FARS data from calendar years 1997 to 2003.

The analysis compares specific make/models of passenger cars and SUVs with ESC versus earlier versions of the same make/models, using multi-vehicle crash involvements as a control group. Vehicles with ESC as optional equipment were not included in the analysis because we could not determine which vehicles had ESC and which did not.[1] Our passenger car sample for the time being consists of mainly Mercedes-Benz and BMW models (61 percent). Mercedes-Benz installed ESC in certain luxury models in 1997 and had made it standard equipment in all their models (except one) by 2000. BMW also installed ESC in certain 5, 7, and 8 series models as early as 1997 and had made it standard equipment in all their models by 2001. The passenger car sample also includes some luxury GM cars, which constituted 23 percent of the sample, and a few cars from other manufacturers. GM cars where ESC was offered as standard equipment are the Buick Park Avenue Ultra, the Cadillac DeVille, Seville STS and SLS, the Oldsmobile Aurora, the Pontiac Bonneville SSE and SSEi, and the Chevrolet Corvette. The SUV make/models in our study with ESC include Mercedes-Benz (ML320, ML350, ML430, ML500, G500, G55 AMG), Toyota (4Runner, Landcruiser), and Lexus (RX300, LX470).

The first set of analyses uses multi-vehicle crash involvements as a control group, essentially assuming that ESC has no effect on multi-vehicle crashes. However, because non-fatal multi-vehicle crashes are far more common than single vehicle crashes, it is at least conceivable that a small relative increase in multi-vehicle crashes could easily offset the reduction in single vehicle crashes (not that there is any intuitive basis for anticipating such an increase). Thus, linear regression analyses were also performed to look at the single- and multi-vehicle crash involvement rates per 100,000 vehicle registration years, controlling for vehicle age, to ascertain the effect, if any, of ESC on multi-vehicle crash involvements.

Results Specific make/models with ESC were compared with earlier versions of similar make/models using multi-vehicle crash involvements as a control group, creating 2x2 contingency tables as shown

[1] We did examine those make/models that had ESC as optional equipment, under the assumption that all these vehicles did not have ESC, and these additional data did not make a big difference in the overall effectiveness.

in Tables 1 and 2. We found that single vehicle crashes were reduced by

$$1 - \{(699/1483)/(14090/19444)\} = 35 \text{ percent}$$

in passenger cars and by 67 percent in SUVs (Table 1). Similarly, fatal single vehicle crashes are reduced by 30 percent in cars and by 63 percent in SUVs (Table 2). Reductions of single vehicle crashes in passenger cars and SUVs are statistically significant at the .01 level, as evidenced by chi-square statistics exceeding 6.64 in each 2x2 contingency table (Table 1). Reductions of fatal single vehicle crashes are statistically significant at the .01 level in SUVs and at the .05 level in passenger cars with chi-square statistic greater than 3.84 (Table 2).

***Table 1:* Effectiveness of ESC in Reducing Single Vehicle Crashes in Passenger Cars and SUVs (1997-2002 crash data from five States)**

Passenger Cars	**Single Vehicle Crashes**	**Multi-Vehicle Crashes**
No ESC	1483	19444
ESC	699	14090
Percent reduction in single vehicle crashes in passenger cars with ESC	**35.0 %**	
Approximate 95 percent confidence bounds	29% to 41%	
Chi-square value	84.1	
SUVs	**Single Vehicle Crashes**	**Multi-Vehicle Crashes**
No ESC	512	6510
ESC	95	3661
Percent reduction in single vehicle crashes in SUVs with ESC	**67.0 %**	
Approximate 95 percent confidence bounds	60% to 74%	
Chi-square value	104.4	

***Table 2:* Effectiveness of ESC in Reducing Fatal Single Vehicle Crashes in Passenger Cars and SUVs (1997-2003 FARS data)**

Passenger Cars	**Fatal Single Vehicle Crashes**	**Fatal Multi-Vehicle Crashes**
No ESC	186	330
ESC	110	278
Percent reduction in fatal single vehicle crashes in passenger cars with ESC	**30.0 %**	
Approximate 95 percent confidence bounds	10% to 50%	
Chi-square value	6.0	
SUVs	**Fatal Single Vehicle Crashes**	**Fatal Multi-Vehicle Crashes**
No ESC	129	199
ESC	25	103
Percent reduction in fatal single vehicle crashes in SUVs with ESC	**63.0 %**	
Approximate 95 percent confidence bounds	44% to 81%	
Chi-square value	16.1	

As a check, we also ran logistic regression analyses on the effect of passenger car ESC on the proportion of crash involvements that are single-vehicle, also controlling for vehicle age and make-model group, driver age and gender. These produced effectiveness estimates for ESC similar to Tables 1 and 2.

The second set of analyses shows significant or borderline-significant reductions in the multi-vehicle crash rates per 100,000 vehicle years with ESC, let alone any increase (and, of course, it also shows significant reductions in the single vehicle crash rates with ESC). Thus, for the time being, we do not see any negative side effect in multi-vehicle crashes that could compromise the very positive findings in single vehicle crashes. Ideally, the control group should not be affected at all by the countermeasure. Using multi-vehicle crashes as the control group, when it is possible that multi-vehicle crashes are being reduced by ESC, actually means that the true effectiveness of ESC could even be higher than we estimated for single vehicle crashes.

We also examined belt use among the ESC and non-ESC groups as a check to see whether a difference in belt use among the small sample could be influencing the results. For passenger cars, belt use in FARS was essentially equal. Thus, belt use does not appear to be a factor for passenger cars. For SUVs, belt use in single vehicle crashes was higher among occupants in the ESC group (58 percent) than among the non-ESC group (49 percent). This might have inflated the effectiveness for ESC in single vehicle fatalities for SUVs. Again, these are based on small samples.

ESC appears to be highly effective in reducing single vehicle run-off-road crashes such as rollovers and collisions with fixed objects. One caveat on this preliminary conclusion is that it is based primarily on crash data involving BMW and Mercedes-Benz passenger cars, the first two manufacturers that installed ESC as standard equipment on most of their fleet. As mentioned earlier, their vehicles constituted 61 percent of the passenger cars in our sample. When data on cars from each individual manufacturer are analyzed separately, results are positive for all the manufacturers, but statistically significant only for Mercedes and BMW, the only two with large sample sizes at this time. Results from the SUV crash data analyses are not only positive but also statistically significant for each of the three manufacturers (Mercedes-Benz, Toyota, Lexus). Toyota and Lexus models constituted 78 percent of the SUVs in our sample. Effectiveness could vary among manufacturers not only because of possible differences in the ESC equipment, but also because of the types of drivers (age, gender) and the locations where the vehicles are used (urban, rural, flat, hilly, wet, dry). Also, some of the make-models included in the study received design changes, other than ESC, that conceivably might have influenced the ratio of single- to multi-vehicle crash involvements. NHTSA will feel more confident about the overall effectiveness of ESC when we have enough data on a more representative cross-section of the fleet including non-luxury vehicles and a wider variety of manufacturers. That is likely to take at least another year or two.

For more information about this study, please contact Jennifer N. Dang at 202-493-0598. This note and other NHTSA evaluations may be viewed at www.nhtsa.dot.gov/cars/rules/regrev/evaluate/809790.html.