FIELD PERFORMANCE STUDY OF ELECTRONIC STABILITY CONTROL SYSTEM EFFECTIVENESS IN US FATAL CRASHES

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ABSTRACT

Recent US field data was used to evaluate the effectiveness of Electronic Stability Control (ESC) systems in reducing fatal crashes. Light vehicles with and without ESC systems were compared through comprehensive statistical analysis, including logistic regression and contingency analyses, to address ESC effectiveness in single- and multiple-vehicle, rollover and nonrollover crashes. Analyses controlled for key driver, vehicular, and environmental factors. Results indicate ESC systems are highly effective for rollovers in which the rollover is the first harmful event, but less effective for other rollovers and not effective for reducing fatal nonrollover crashes.

Keywords: accident analysis, ESC, rollover, stability, system effectiveness

DUE TO THE relatively recent emergence of Electronic Stability Control (ESC) systems, there is still a limited amount of data on the safety performance of vehicles with ESC systems in real-world crashes, and the field performance data that does exist is primarily for high-end, luxury vehicles (because the systems were first offered as standard equipment in these vehicles). There are also differences between the ESC systems implemented by different manufacturers. However, regulatory attention being focused on the emerging ESC technology has created a present need for definitive studies. The primary objective of the research reported here was to examine field data to determine the effectiveness of ESC systems in reducing fatal single- and multiple- vehicle crashes for passenger car and light truck models with ESC systems available as standard equipment. This paper presents findings and conclusions as to the effectiveness of ESC systems in reducing fatal crashes.

BACKGROUND

In the past few years, various studies have been published that purport to evaluate the effectiveness of ESC systems. However, most of these studies looked at very few vehicles, and the vehicles that were included tended to be high-end luxury models—both factors that can greatly influence results. The following, while not an exhaustive listing of past ESC studies[1], offers an overview of some of the more recent studies and their findings.

Toyota performed a study of "vehicle stability control" systems that examined crash data for only three Toyota passenger car models to measure ESC effectiveness in reducing accidents in Japan (Aga and Okada, 2003). Effectiveness comparisons made for single-vehicle and head-on crashes (accidents per 10,000 vehicles in use per year) found a 35% reduction in the number of single-vehicle crashes and a 30% reduction in head-on collisions.

Similarly, a study by Mercedes-Benz (2006) examined the effectiveness of their proprietary ESC system in Mercedes passenger cars. Based on the number of accidents for "newly registered Mercedes models" in 1.5 million traffic accidents in Germany, the study found a 15% reduction in accident rates for Mercedes due to the addition of ESC systems. The study also showed that the proportion of ESC-equipped Mercedes passenger cars in rollover accidents was about 12% lower than for vehicles without ESC.

A Swedish study, guided by the results of field data studies (specifically Sferco et al., 2001) utilizing European Accident Causation Survey data, examined serious and fatal loss-of-control type crashes on wet and icy/snowy road surfaces (Lie, 2005). That study, which focused on cars only and included more vehicle model series (43 trim-levels) than either the Toyota or Mercedes studies, found

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[1] For more reading on this subject: *Exposure Data and Primary Safety* (Räty, et al, 2006) a SARAC II report, lists the most recent ESC studies, worldwide, and Aga and Okada (2003) offer good background information on earlier studies.

an ESC effectiveness of 25% for serious and fatal crashes on dry roads, 56% on wet roads, and 49% on roads covered with ice and snow.

In the United States (US), an early Insurance Institute for Highway Safety (IIHS) study (Farmer, 2004) looked at all police-reported crashes in seven states over a two-year period, and fatal crashes in the US over a three-year period, for cars and sport utility vehicles (SUVs). Comparing identical 2000-2002 models with/without ESC systems, the study found ESC systems account for a 41% reduction in single-vehicle crashes in general and a 56% reduction in fatal single-vehicle crashes. Rates for multiple-vehicle crashes were not found to be significant.

Both Pacific Institute for Research and Evaluation (PIRE) and University of Michigan Transportation Research Institute (UMTRI) studies evaluated effectiveness in cars and SUVs on US roads. The PIRE study combined cars and trucks (Bahouth, 2005) and found a 53% reduction in single-vehicle crashes and a 12% reduction in multiple-vehicle crashes. The UMTRI study used 2x2 contingency table analysis methods to examine cars and SUVs separately for crashes "generally associated with loss of control." The study used US National Highway Traffic Safety Administration (NHTSA) General Estimates System (GES) files to examine all crashes and Fatality Analysis Reporting System (FARS) data to examine fatal crashes. The FARS-based analyses estimated a 30% reduction in the odds of fatal single-vehicle crashes for cars with ESC systems, and 50% reduction for SUVs (Green and Woodrooffe, 2006). The UMTRI study also used FARS data to evaluate rollover crashes, estimating ESC systems would reduce odds of fatal rollover crashes by 40% for cars and 73% for SUVs.

Not all ESC studies have relied on crash data. In a simulator-based experiment of 120 subjects in simulated loss-of-control situations with and without ESC systems, Papelis et al., (2004) found ESC systems 88% effective (i.e., an 88% reduction in loss of control). The study attempted to account for driver age and gender and vehicle/system configuration differences for three on-road driving "events" (incursion, curve, and wind). Even with pronounced differences in results between the two vehicles used, the simulations seem to show that: "In all cases, there was a benefit to having the system" (Papelis et al., 2004).

One of the largest of the recent field performance evaluations is the NHTSA ESC study. Preliminary analysis results, published as an Evaluation Note (Dang, 2004), received widespread attention, and the final study findings were formally issued as a Draft Technical Report (Dang, 2006). The NHTSA study evaluated FARS data for 1997 to 2004 model year passenger cars and light trucks and found ESC systems to be effective in reducing fatal single-vehicle "run-off-road" crashes (the main crash category) by 35% for passenger cars and 72% for light trucks. Additionally, the study's examination of (mostly non-fatal) police-reported crash data from seven states found ESC to be effective in reducing single-vehicle "run-off-road" crashes by 46% for passenger cars and 75% for light trucks.

NHTSA has also issued a recent Preliminary Regulatory Impact Analysis (PRIA) that cites the 2004 and 2006 ESC study results (among others) as support for a Federal Motor Vehicle Safety Standard (FMVSS) to require light vehicles be equipped with ESC systems (NHTSA, 2006). The PRIA uses the ESC study findings as a basis for recommending FMVSS No. 126 apply to "passenger cars, multipurpose passenger vehicles, trucks, and buses" with a GVWR of 10,000 pounds or less, even though the NHTSA ESC study does not in fact contain *any* pickup trucks or minivans (none of these being available in the database of ESC-equipped vehicles used for that study). In fact, the NHTSA ESC study notes that "even as of 2004, a large proportion of the vehicles equipped with ESC were still luxury vehicles." Such wide-scale application of early and admittedly incomplete results has intensified the need for repeated and increasingly in-depth studies, such as the one presented in this paper, as additional data becomes available.

DATA SOURCES

VEHICLE SELECTION DATA. The first step in the analysis was to identify vehicles with ESC systems available as standard equipment. This meant identifying makes, models, and series down to detailed trim levels. To do this, the study used a variety of sources, including websites such as iihs.org, safercar.gov, and msnauto.com. The identification of ESC-equipped vehicles resulted in nearly 700 vehicle trim levels (mostly 2004/2005 models) for this study.

FIELD PERFORMANCE DATA. FARS data (calendar years 1993-2004) was used to address the risk of involvement in fatal crashes. Because of the regulatory significance attached to the NHTSA report findings in the US, this study first matched the fatal crash categories described in the NHTSA ESC report, then extended the investigation to more vehicles and a wider range of crash conditions.

FARS is a census of all US traffic crashes that occur on public roads and result in death within 30 days of the crash. FARS data is compiled from police accident reports, vehicle registration files, driver licensing files, death certificates, medical examiner reports, state highway department data, and hospital/EMS records, and extensive quality control procedures are used by the state and federal FARS technical professionals to ensure accuracy and completeness of each piece of information entered into the database. Because more than 100 data elements associated with accident, vehicle, and occupant-related factors are coded for each fatal traffic crash, FARS data files are widely used by crash and vehicle safety investigators.

METHOD

IDENTIFYING ESC SYSTEM AVAILABILITY. Models with ESC systems were compared with the same models for the three years prior to introduction of ESC as standard equipment for those models. Vehicle data for each make/model/series, body type, and model year were used to identify when ESC systems became standard equipment. The goal was to select as many vehicles from model years 1995 through 2005 as possible in order to assure a large database and accurately reflect the on-road population of vehicles with ESC systems (1997 was essentially the first year the systems were available on US vehicles, although as early as 1996 a very few luxury models were optionally equipped with ESC systems and two BMW models offered it as standard equipment). Even with the study's inclusion of 2005 models, many of the vehicles in the resulting study database are luxury vehicles.

DEFINING CRASH TYPES. The study defined a "control group" (crashes ESC would not prevent) and "response group" (crashes ESC would most likely prevent) to address the effectiveness of ESC systems. The control group included "Crash involvements in which a vehicle 1) was stopped, parked, backing up, or entering/leaving a parking space prior to the crash, 2) traveled at a speed less than 10 mph, 3) was struck in the rear by another vehicle, or 4) was a non-culpable party in a multi-vehicle crash on a dry road" (Dang, 2006). Categories that differ from those the present study original to the NHTSA study include nonrollovers as a category, rollovers that were not single-vehicle crashes, or rollover crashes for which rollover was not coded as the first harmful event.

- **Single-Vehicle Relevant Crashes**—Corresponds to NHTSA report's "All run-off-road" category. In brief, the All SVA Relevant category includes all single-vehicle crashes EXCEPT those that fit the definitions for "collision with pedestrian/bicycle/animal" or "other single-vehicle crash" (see following). The subcategories defined below, while examined as part of "All SVA Relevant," were also considered singly in both this study and the NHTSA study:
  - **Side-Impact with Fixed Object**—Corresponds to NHTSA's "Run-off-road– Side impact with fixed object": A single-vehicle collision with a fixed object in which the vehicle sustains an initial impact on the side.
  - **Single-Vehicle Crash, First Harmful Event Rollover**—Corresponds to NHTSA's "Run-off-road– Rollover": A single-vehicle crash with a first harmful event rollover.
- **Single-Vehicle Collision with Pedestrian/Bicycle/Animal**—NHTSA-matching category. Includes single-vehicle crashes in which the first harmful event is a collision with a pedestrian, bicycle, or animal.
- **Other Single-Vehicle Crashes**—NHTSA-matching category. Includes single-vehicle crashes in which the first harmful event is 1) a collision with a parked vehicle, a train, or a thrown or falling object or 2) a fire, an explosion, or a fall from the vehicle.
- **Single-Vehicle Rollovers Not First Harmful Event**—Included to pick up all single-vehicle rollovers where rollover is NOT the first harmful event.
- **All Single-Vehicle Nonrollovers**—Included to examine all single-vehicle nonrollovers (coded NOT rollover).
- **All Single-Vehicle Crashes**—Included to examine all single-vehicle crashes.

- **Culpable Multiple-Vehicle Crashes**—NHTSA-matching category. Includes multiple-vehicle crashes where vehicle is NOT starting, parking, backing up, stopped/parked, or otherwise traveling no faster than 10 mph (16 kph); the road surface condition is dry or wet (but not dirt, sand, oil, other, or unknown); and the manner of collision is rear-end (initial impact to fatal vehicle front) or angle/sideswipe/head-on (with culpable driver).
- **All MVA Rollovers**—Included to examine all multiple-vehicle rollovers.
- **All MVA Nonrollovers—**Included to examine all multiple-vehicle nonrollovers (coded NOT rollover).
- **All MVA—**Included to examine all multiple-vehicle crashes.
- **All Relevant Single-Vehicle/Pedestrian/Multiple-Vehicle Crashes**—NHTSA-matching category (called "All single, pedestrian, and culpable multi-vehicle" for the NHTSA FARS analysis). Includes all single-vehicle and "Culpable multiple-vehicle" (see definition, above) crashes.
- **All Rollovers**—Included to examine all rollovers (single- and multiple vehicle).
- **All Nonrollovers**—Included to examine all nonrollovers (single- and multiple vehicle). The category includes all crashes in which rollover was coded "unknown."

ANALYZING ESC SYSTEM EFFECTIVENESS. The basic approach was to estimate the reduction of crash involvements of the types most likely to have benefited from ESC-relative to a control group of other types of crashes where ESC is unlikely to have made a difference. Once ESC-equipped vehicles were identified and crash categories defined, analyses were performed to evaluate how effective the systems might be in reducing the occurrence of fatal single- and multiple-vehicle crashes, by crash type.

The FARS analyses used data for 1994-2005 model year vehicles in calendar years 1993-2004; the wider range of calendar years was chosen to ensure capturing crashes involving "same models" *without* ESC systems for comparison to models *with* ESC systems. After selecting for ESC and ESC-sister vehicles, the resulting FARS data set consisted of 1,966 passenger cars and 1,833 light trucks.

Multiple logistic regression (Hosmer and Lemeshow, 2000) was used to perform ESC system effectiveness analyses for all categories of fatal crashes identified for this study. Logistic regression allows the analyst to control for factors other than ESC in order to ensure that these factors, such as belt use, driver age, driver gender, vehicle age, time of day, location of crash (rural/urban, freeway), driver drinking, and vehicle make, do not obscure or confound the effects of ESC systems on accidents. Factors other than the presence of ESC systems were examined for vehicles with and without ESC to address the relative contribution of factors in reducing crash-involvement rates.

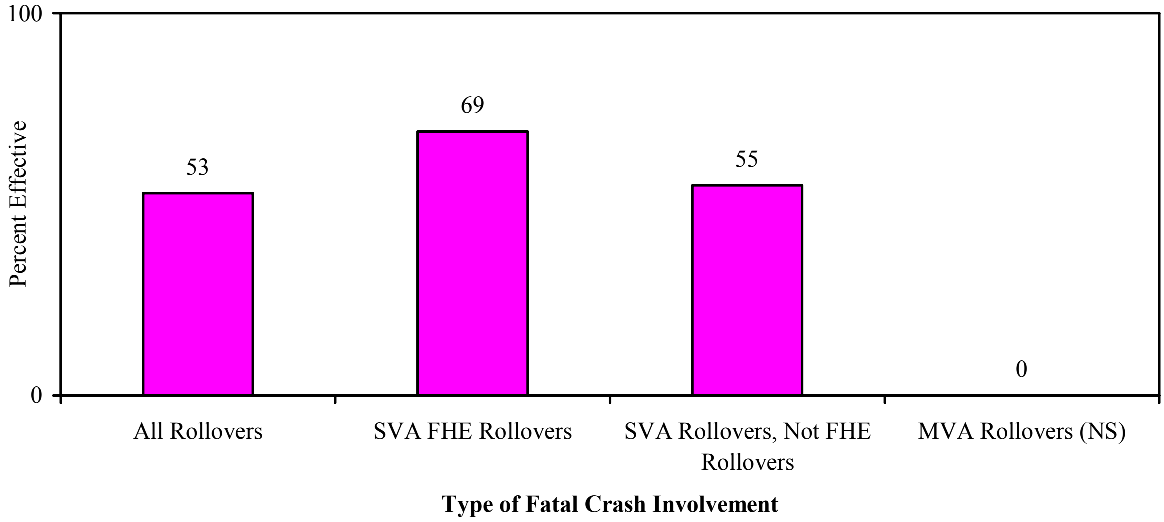
RESULTS

Overall, the study shows that, for passenger cars, ESC systems are effective in reducing fatalities for all single-vehicle rollovers but not for multiple-vehicle rollovers. For all other types of fatal passenger car crashes (all fatal single-vehicle, single-vehicle non-rollover, and multiple vehicle non-rollover), ESC system effectiveness is not statistically significant.

For light trucks, ESC systems are highly effective for reducing one type of fatal rollover: single-vehicle crashes where the fatal rollover is the first harmful event. For other types of light truck rollover crashes (i.e., where the first harmful events include collision with tree/pole/post/signal/ guardrail or ditch/embankment), ESC system effectiveness is not statistically significant. These other types of rollovers are primarily off-road rollover crashes. In addition, for all other types of fatal light truck crashes (all fatal single-vehicle, single-vehicle non-rollover, multiple-vehicle rollover, and multiple-vehicle non-rollover), ESC system effectiveness is not statistically significant.

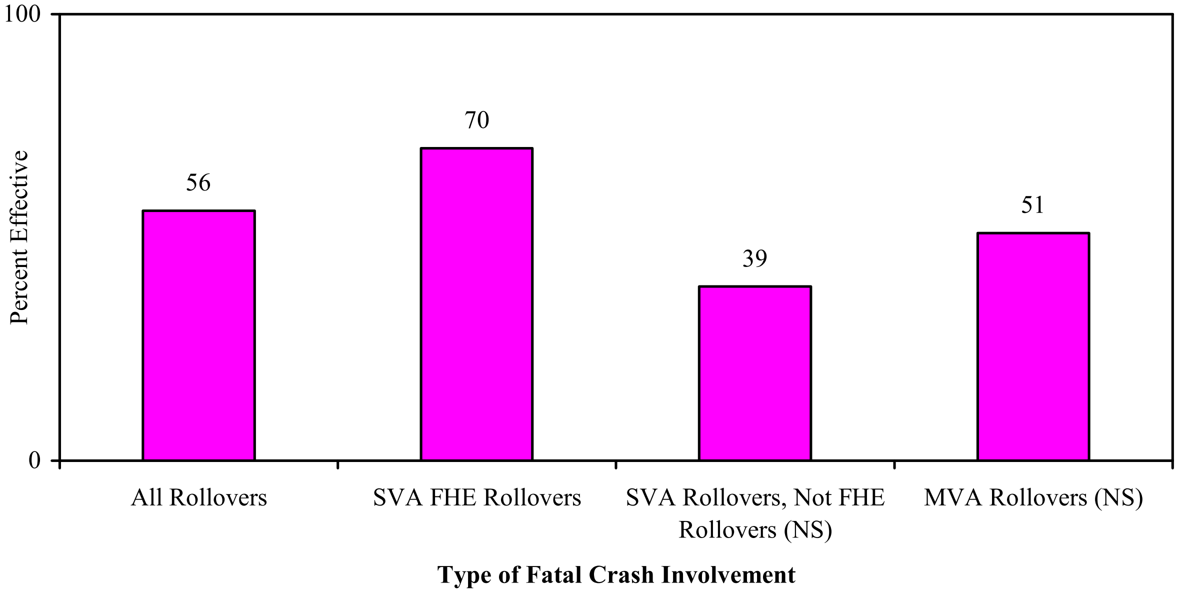
ESC EFFECTIVENESS IN FATAL ROLLOVER CRASHES. Figures 1 and 2 show results for fatal single-vehicle rollovers where rollover was the first harmful event, fatal single-vehicle rollovers where rollover was *not* first harmful event, and fatal multiple-vehicle rollovers.

Figure 1. ESC Effectiveness in Fatal Rollover Crashes
Passenger Cars



Source: FARS, 1993-2004. ESC effectiveness based on logistic model. SVA = single-vehicle accident; MVA = multiple-vehicle accident; FHE = first harmful event; and NS = Not significant.

Figure 2. ESC Effectiveness in Fatal Rollover Crashes
Light Trucks



Source: FARS, 1993-2004. ESC effectiveness based on logistic model. SVA = single-vehicle accident; MVA = multiple-vehicle accident; FHE = first harmful event; and NS = Not significant.

Table 1 presents effectiveness estimates and upper and lower bounds for this series. As the data shows, ESC is highly effective for all single vehicle first harmful rollovers (69% for cars and 70% for light trucks). However, ESC effectiveness estimates are not statistically significant for either passenger car or light truck *multiple-vehicle* rollover crashes. For single-vehicle rollovers that are *not* first harmful event, ESC is significantly effective for cars (55%) but not for light trucks (39%).

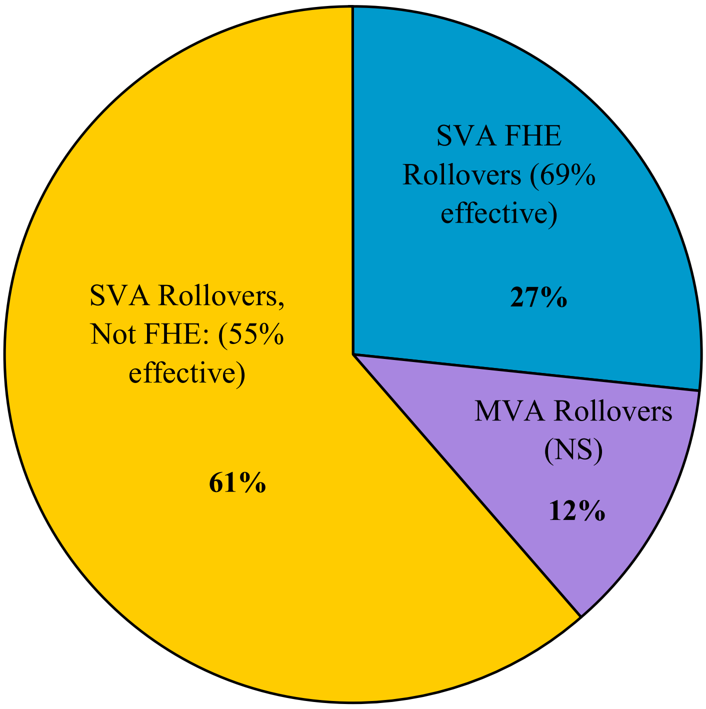
Table 1. Confidence Bounds on ESC Effectiveness Estimates for Fatal Rollovers

Passenger Cars	Effectiveness	95% Lower Bound	95% Upper Bound	P-Value*
All Rollovers	52.5	14.6	73.6	0.013
SVA FHE Rollovers	69.1	16.5	88.6	0.021
SVA Not FHE Rollovers	54.5	6.0	78.0	0.033
MVA Rollovers	-7.8	-215.6	63.2	0.891
Light Trucks	**Effectiveness**	**95% Lower Bound**	**95% Upper Bound**	**P-Value***
All Rollovers	55.6	23.4	74.2	0.004
SVA FHE Rollovers	70.0	34.5	86.2	0.003
SVA Not FHE Rollovers	38.8	-43.2	73.9	0.257
MVA Rollovers	51.0	-14.7	79.1	0.1

*Estimates with a p-value greater than 0.05 (5% error band) are not statistically significant.
Source: FARS, 1993-2004. ESC effectiveness based on logistic model. SVA = single-vehicle accident; MVA = multiple-vehicle accident; and FHE = first harmful event.

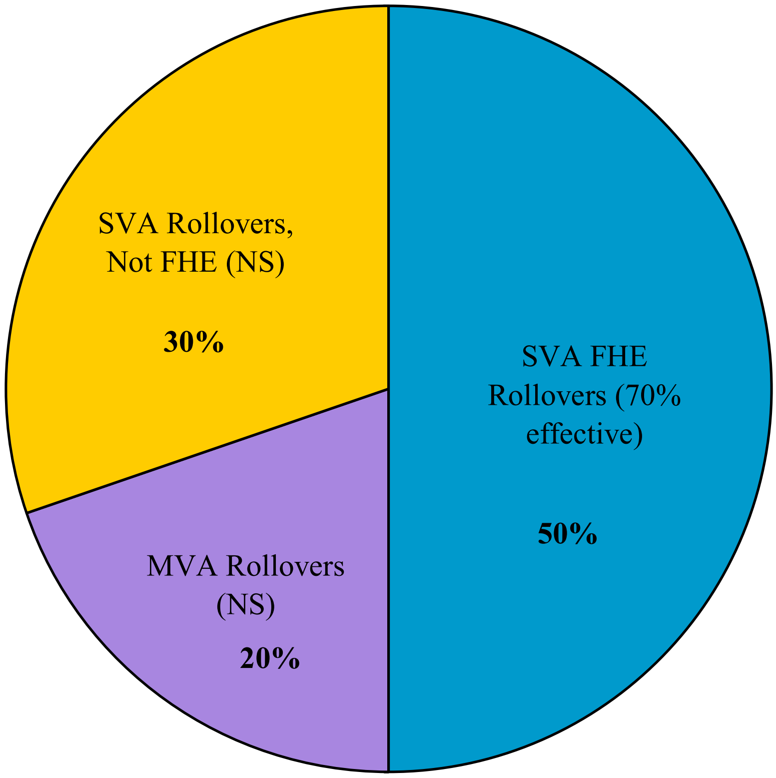
FATAL ROLLOVER CRASHES, BY ROLLOVER CRASH TYPES. This study also examined how often each type of fatal rollover occurs. For passenger cars (Figure 3), the first harmful event rollovers are only 27% of the total; for light trucks (Figure 4), they are approximately half. For multiple-vehicle rollovers, which account for 12% of all fatal passenger car rollover crashes and 20% of all fatal light truck rollover crashes, ESC systems appear *not* to be effective.

Figure 3. Rollover Vehicles in Fatal Crashes: Passenger Cars, by Rollover Type



Source: FARS, 1993-2004. ESC effectiveness based on logistic model. SVA = single-vehicle accident; MVA = multiple-vehicle accident; FHE = first harmful event; and NS = Not significant.

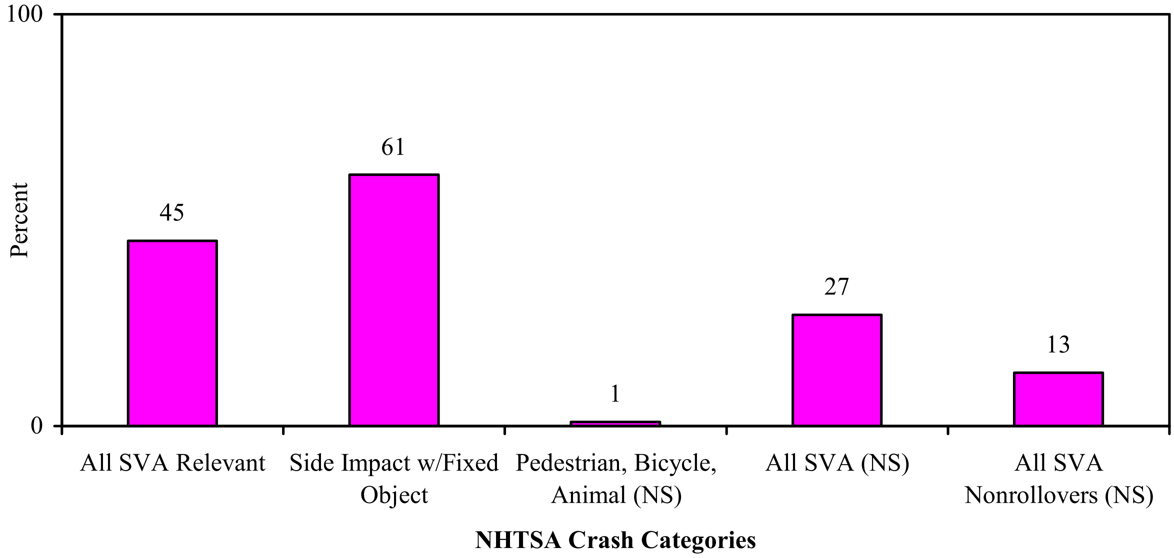
Figure 4. Rollover Vehicles in Fatal Crashes:
Light Trucks, by Rollover Type



Source: FARS, 1993-2004. ESC effectiveness based on logistic model. SVA = single-vehicle accident; MVA = multiple-vehicle accident; FHE = first harmful event; and NS = Not significant.

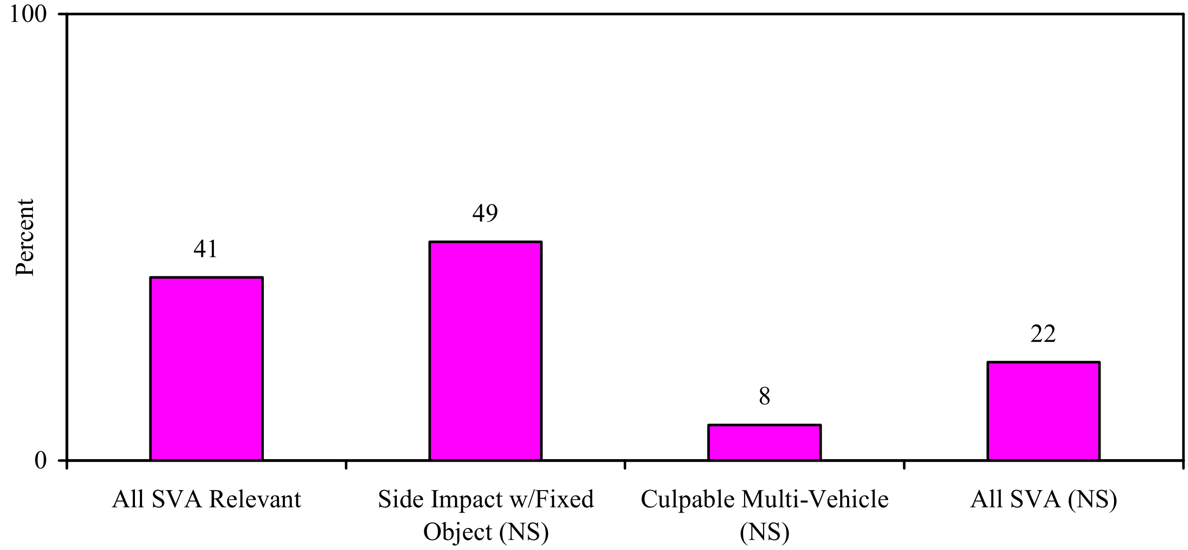
ESC EFFECTIVENESS IN FATAL NONROLLOVERS, OTHER CATEGORIES. Figures 5 and 6 show results for which crash categories (other than rollover) for which effectiveness was above

Figure 5. ESC Effectiveness in Nonrollover/Other Fatal Crashes,
Passenger Cars



Source: FARS, 1993-2004. Estimates are based on logistic model. NS = Not significant.

Figure 6. ESC Effectiveness in Nonrollover/Other Fatal Crashes, Light Trucks



Sources: FARS, 1993-2004. Estimates are based on logistic model. NS = Not significant.

Table. 2. Confidence Bounds on ESC Effectiveness Estimates for Nonrollover/Other Fatal Crash Categories

Passenger Cars	Effectiveness	95% Lower Bound	95% Upper Bound	P-Value*
All SVA Relevant	44.7	12.8	64.9	0.01
Side Impact w/Fixed Object	61.4	11.6	83.2	0.02
Pedestrian/Bicycle/ Animal	1.2	-63.4	40.3	0.96
Culpable Multiple-Vehicle	-9.7	-55.6	22.7	0.60
All SVA	27.3	-4.8	49.6	0.09
All SVA Non-Rollover	13.0	-28.0	40.8	0.48
All MVA	-4.7	-42.8	23.2	0.77
All MVA Non-Rollover	-5.0	-43.5	23.2	0.76
Light Trucks	Effectiveness	95% Lower Bound	95% Upper Bound	P-Value*
All SVA Relevant	40.7	-1.2	65.3	0.055
Side Impact w/Fixed Object	48.7	-138.3	89.0	0.39
Pedestrian/Bicycle/ Animal	-20.3	-113.6	32.2	0.53
Culpable Multiple-Vehicle	8.4	-46.8	42.9	0.72
All SVA	21.6	-18.6	48.1	0.25
All SVA Non-Rollover	-20.4	-96.6	26.3	0.46
All MVA	-2.8	-52.0	30.5	0.89
All MVA Non-Rollover	-17.5	-76.5	21.7	0.44

*Estimates with a p-value greater than 0.05 (5% error band) are not statistically significant.

Source: FARS, 1993-2004. ESC effectiveness based on logistic model. SVA = single-vehicle accident and MVA = multiple-vehicle accident.

zero. These include categories for *all* single-vehicle and multiple-vehicle crashes, and all nonrollover single-vehicle and multiple-vehicle crashes. Table 2 provides confidence bounds for all the logistic model results, including those not shown in the figures. Overall, with a few limited NHTSA crash categories noted, the results suggest that ESC has very little effect on crashes other than rollovers. However, as Table 2 shows, few of these findings have statistical significance.

DISCUSSION

LIMITATIONS. The overriding limitation of this and all other currently available field data studies of ESC systems is that ESC systems are relatively new, which limits the amount of data available for study. Also, the systems were first introduced in high-end vehicles, which may have some effect on comparisons of vehicles with and without ESC, particularly for the earlier years. Finally, ESC system implementation differs by manufacturer, and while manufacturers were included in the logistic analyses, there are not yet large enough numbers of crash-involved vehicles equipped with ESC systems to show statistically significant variations of ESC effectiveness by manufacturer.

COMPARISON WITH THE NHTSA STUDY. A secondary objective of this study was to compare fatal crash effectiveness results with those presented in the NHTSA ESC report (Dang, 2006). Of the vehicle trim levels identified for this study, approximately 180 matched the trim levels used in the NHTSA study.

NHTSA's FARS analysis covered fatal crash involvement for 1997-2004 model year vehicles in calendar years 1997-2004 and relied on 2x2 contingency tables to compare fatal crashes for vehicles with and without ESC systems. NHTSA used logistic regression analyses for only one type of fatal crashes and only to confirm the results from the contingency analyses. The NHTSA logistic models (unlike those used in the present study) had no controls for driver drinking, vehicle age, or most important of all, belt use. When these control factors are introduced in the models, ESC system effectiveness is much lower (or statistically insignificant) than NHTSA study results show for some of the crash types. Field data shows that many of these rollovers are associated with a high percentage of alcohol impairment, speeding, or night time crashes.

NHTSA did not examine ESC system effectiveness for nonrollover crashes separately from rollover crashes nor consider all single-vehicle and all multiple-vehicle crashes separately from other categories. However, analysis shows strong indications that ESC is much less effective for these categories than it is for rollovers; therefore, these categories should be re-examined as more years of data become available.

CONCLUSIONS

Based on the findings of the FARS data analyses, this paper concludes ESC systems are highly effective for fatal single-vehicle rollovers in which the rollover is the first harmful event. For light trucks, ESC is not significantly effective for single-vehicle rollovers where the first harmful events include collision with tree/pole/post/guardrail/culvert or ditch/embankment. These types of rollover crashes are primarily off-road rollover crashes. For both passenger cars and light trucks, ESC is not significantly effective in reducing fatal multiple-vehicle rollovers. Additionally, limited data to date shows that ESC is not significantly effective in reducing fatal *non*rollover crashes.

REFERENCES

Aga, Masami and Akio Okada (2003). "Analysis of Vehicle Stability Control's Effectiveness from Accident Data", Toyota Motor Corporation (Japan) and Toyota Techno Service Corporation (Japan), ESV Paper No. 541, 2003.

Bahouth, George T. (2005). "Real World Crash Evaluation of Vehicle Stability Control Technology," PIRE, September 2005.

Dang, Jennifer N. (2006). "Statistical Analysis of the Effectiveness of Electronic Stability Control (ESC) Systems," NHTSA Draft Technical Report, US Department of Transportation, Washington, D.C., September 2006.

Dang, Jennifer N. (2004). "Preliminary Results Analyzing the Effectiveness of Electronic Stability Control (ESC) Systems," NHTSA Evaluation Note, DOT HS 809 790, US Department of Transportation, Washington, D.C., 2004.

Farmer, Charles M. (2004). “Effect of Electronic Stability Control on Automobile Crash Risk,” study for Insurance Institute for Highway Safety, Arlington, Virginia, published in *Traffic Injury Prevention*, Vol. 5, pp. 317-325, October 2004.

Green, P.E. and J. Woodrooffe (2006). “The Effectiveness of Electronic Stability Control on Motor Vehicle Crash Prevention,” University of Michigan, Transportation Research Institute report, UMTRI-2006-12 April 2006.

Hosmer, David W., Jr., and Stanley Lemeshow (2000). *Applied Logistic Regression,* Second Edition, Wiley Series (Probability and Statistics), September 15, 2000.

Lie, Anders, Claes Tingvall, Maria Krafft, and Anders Kullgren (2005). “The Effectiveness of ESC (Electronic Stability Control) in Reducing Real Life Crashes and Injuries,” 19th International Technical Conference on the Enhanced Safety of Vehicles Conference (ESV), June 2005.

Mercedes-Benz (2006). “Updated Accident Statistics: Mercedes Cars Have Fewer Accidents,” ESP® press release, November 2006 [captured from Continental Teves, Inc. on January 22, 2007, at www.contitevesna.com/pdfs/MercedesStudyPressInfo.pdf].

National Highway Traffic Safety Administration (2006). “Proposed FMVSS No. 126: Electronic Stability Control Systems,” Preliminary Regulatory Impact Analysis, Office of Regulatory Analysis and Evaluation National Center for Statistics and Analysis, August 2006.

Papelis Y., T. Brown, G. Watson, D. Holtz, and W. Pan (2004). “Study of ESC-Assisted Driver Performance Using a Driving Simulator,” Report No. N04–003-PR, University of Iowa, 2004.

Räty, Esa, Timo Ernvall, and Jens-Peter Kreiss (2006). Exposure Data and Primary Safety, SARAC II (Quality Criteria for the Safety Assessment of Cars Based on Real-World Crashes), Sub-Task 3.1 report, January 2006. [Performing organizations: Laboratory of Transportation Engineering (Helsinki University of Technology) and Institut für Mathematische Stochastik (TU Braunschweig), Project No. SUBB27020B-E3-S07.17321-2002, funded by the European Commission.]

Sferco, R., Y. Page, J-Y. Le Coz, and P. Fay (2001). “Potential Effectiveness of Electronic Stability Programs (ESP) – What European Field Studies Tell Us,” 17th International Technical Conference on the Enhanced Safety of Vehicles, Amsterdam, ESV paper No. 2001-S2-O-327, June 2001.