ROLL STABILITY SYSTEMS:
COST-BENEFIT ANALYSIS OF ROLL STABILITY CONTROL VERSUS ELECTRONIC STABILITY CONTROL USING EMPIRICAL CRASH DATA

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1.0 INTRODUCTION

Crashes involving large trucks create numerous impacts on the transportation system and its users, including property damage, injuries and fatalities. To address two of the more consequential crash types -- truck rollovers and loss of control crashes (LOC) -- many motor carriers are deploying roll stability systems (RSS). These technology systems are designed to take active control of a vehicle and apply corrective actions when a truck's movements become unstable. There are two primary stability control systems for large trucks: Roll Stability Control (RSC) and Electronic Stability Control (ESC). RSC systems typically activate when the truck is at risk of experiencing an un-tripped rollover. ESC systems will activate when rollover instability is detected as well as when LOC crashes are likely due to yaw instability (e.g. jackknife).

In May 2012, the National Highway Traffic Safety Administration (NHTSA) proposed a new federal motor vehicle safety standard (FMVSS) which would mandate ESC on all new truck tractors with a gross vehicle weight rating (GVWR) greater than 26,000 pounds. Given the relatively nascent state of the technology, the underlying studies that informed the ESC FMVSS were based on limited field tests, as opposed to empirical operational crash data. However, as market penetration of both systems increases, certain industry stakeholders believe that, despite the fact ESC has greater functionality than RSC, the higher per-unit cost of ESC may not make it as "cost-effective" as RSC.

The testing of this hypothesis was identified by the American Transportation Research Institute's (ATRI) Research Advisory Committee as a top research priority for 2012.[1] ATRI's methodology involved the collection of empirical truck crash data from actual motor carrier operations. These data included a large sample of trucks equipped with RSC, ESC or no RSS system, and documented the relevant crash types and associated costs for trucks with and without the RSS systems. The research objective is to quantify the role of RSC and ESC in crash reduction relative to the cost of each system using operational crash data.

2.0 LITERATURE REVIEW

RSS are generally designed to prevent two types of crashes: un-tripped rollovers and loss of control crashes (which can lead to skidding, jackknifing, or rollover). These types of crashes have varying rates of occurrence and severity. Rollovers are relatively rare but are generally quite severe. In 2009 a rollover was categorized as the "most harmful event" in over 8,000 large truck crashes.[2] While this only constituted 2.8

[1] The American Transportation Research Institute (ATRI) Research Advisory Committee (RAC) is comprised of industry stakeholders representing motor carriers, trucking industry suppliers, labor and driver groups, law enforcement, federal government and academia. The RAC is charged with annually recommending a research agenda for the Institute.
[2] *Large Truck and Bus Crash Facts 2009*. Federal Motor Carrier Safety Administration, United States Department of Transportation. Washington, D.C. 2011.

percent of all large truck crashes, rollovers accounted for 52 percent of all large truck occupant fatalities.[3] In addition, based on ATRI's database of insurance industry crash costs, rollover crashes typically compete with rear-end crashes as the single most expensive crash type. Jackknifes are much less common and less severe. A jackknife was the most harmful event in only 0.3 percent of total large truck crashes and 0.1 percent of fatal truck crashes.[4]

As noted, there are two forms of RSS for large trucks, Roll Stability Control (RSC) and Electronic Stability Control (ESC). RSC is designed to primarily prevent un-tripped rollover crashes, while ESC targets both un-tripped rollovers and crashes due to yaw instability (e.g. jackknifes). These two RSS technologies have been in the market for less than ten years; however, adoption of these technologies has been relatively swift over the last five years. RSC first became available for truck tractors in 2002 and by 2007, installation rates had reached an estimated 10.5 percent of new truck tractors sold. RSC installation is expected to increase to16 percent for model year 2012 tractors. ESC was introduced three years later in 2005; by 2007, 7.4 percent of truck tractors sold were equipped with ESC. The ESC installation rate is predicted to reach 26.2 percent for model year 2012 tractors.[5]

There is a high degree of overlap in the type of crashes that RSC and ESC can mitigate. A 2010 Insurance Institute for Highway Safety (IIHS) study found that, of all crashes that could be addressed by a full ESC system, 41 percent could also be addressed by an RSC system. [6] When considering more serious injury and fatality crashes, this percentage increased considerably; RSC systems may address a larger proportion of fatal (65%) and injury (76%) crashes involving rollover that are also addressed by ESC systems. [7] While the IIHS study found that RSC-relevant crashes constituted a large fraction of serious ESC-relevant crashes, researchers did not assert the value of one system as being higher than the other, as the effectiveness of either system's ability to prevent crashes was unknown. The IIHS researchers also conceded the complexity of identifying applicable crashes using datasets such as the Fatal Accident Reporting System (FARS) and General Estimates System (GES). These complications made it difficult to determine the true contributions of RSC versus ESC.

To better understand the efficacy of RSS systems, academics, industry stakeholders and regulatory agencies have conducted numerous studies, field tests, and simulation experiments to investigate the performance of RSC and ESC stability systems. In 2002

[3] *Fatality Facts 2009: Large Trucks*. Highway Safety Research and Communications. [Online] Insurance Institute for Highway Safety. [Cited: October 31, 2011.] http://www.iihs.org/research/fatality_facts_2009/largetrucks.html.
[4] *Large Truck and Bus Crash Facts 2009*. Federal Motor Carrier Safety Administration, United States Department of Transportation. Washington, D.C. 2011.
[5] "*Preliminary Regulatory Impact Analysis: FMVSS No. 136 Electronic Stability Control Systems on Heavy Vehicles.*" National Highway Traffic Safety Administration, United States Department of Transportation. Washington, D.C. 2012.
[6] "Crash Avoidance Potential of Four Large Truck Technologies". Insurance Institute for Highway Safety. Arlington, VA. 2010.
[7] Ibid.

a field operational test (FOT) was conducted to determine the effectiveness of a roll stability advisor and control (RA&C) system in reducing rollover risk as it related to modifying driver behavior.[8] In 2006, the Federal Motor Carrier Safety Administration (FMCSA) conducted research to determine the percent of rollovers due to excessive speed in a curve that could be prevented if RA&C stability systems were implemented nationally. To test the benefits of the enhanced RA&C, a computer simulation tool was developed to reproduce similar driving scenarios to those observed in the previous FOT. The research found that the roll stability control system always intervened at speeds lower than what would cause an unequipped vehicle to roll. The researchers determined that 53 percent of truck rollovers occurring with excessive speeds in a curve could be prevented by RSC and a possible 69 percent reduction for those using the combined RA&C system.[9] Furthermore, the research noted that these intelligent vehicle stability systems could also assist in preventing some run-off road crashes. In fact, due to the volume of run-off road crashes, the study suggested that the RA&C may actually prevent more run-off-road incidents than rollover crashes.

Working with ATRI, FMCSA continued its investigation of roll stability systems and in 2009 published an FMCSA/ATRI cost-benefit analysis of RSC. Findings showed that an estimated 1,422 to 2,037 combination vehicle rollover crashes could be prevented over a five-year period using RSC systems, providing savings of roughly $196,958 per property-damage-only (PDO) rollover crash, $462,470 per injury rollover crash and $1,143,018 per fatal rollover crash.[10]

In 2009, NHTSA published a study conducted by the University of Michigan's Transportation Research Institute (UMTRI) and Meritor WABCO. Researchers concluded that, of the analyzed crashes, approximately 3,500 crashes could be prevented annually by the Meritor WABCO RSC system and approximately 4,700 crashes could be prevented by the ESC system. Furthermore, the decrease in the number of annual heavy truck crashes experienced with ESC installations would also result in the prevention of 126 fatalities and 5,909 injuries with a total savings of $1.738 billion. With RSC, the annual crash reduction would prevent 106 fatalities, 4,384 injuries and generate $1.456 billion in total savings annually.[11]

NHTSA, in 2011, issued a report that described the process of deriving the effectiveness rates of ESC and RSC in truck tractors that it later used to estimate the benefits of these systems. Since RSC and ESC were relatively new and optional, a statistical analysis of vehicles with and without the technology using operational crash data was not feasible at the time. The 2009 FMCSA/ATRI study and a revised version

[8] "Field Operational Test of the Freightliner/Meritor WABCO Roll Stability Advisor and Control at Praxair". University of Michigan Transportation Research Institute. Ann Arbor, MI. 2002.
[9] "A Simulation Approach to Estimate the Efficacy of Meritor WABCO's Improved Roll Stability Control". Federal Motor Carrier Safety Administration, United States Department of Transportation. Washington, D.C. 2006.
[10] "Analysis of Benefits and Costs of Roll Stability Control Systems for the Trucking Industry". Federal Motor Carrier Safety Administration, United States Department of Transportation. Washington, D.C. 2009.
[11] "Safety Benefits of Stability Control Systems for Tractor-Semitrailers". National Highway Traffic Safety Administration, United States Department of Transportation. Washington, D.C. 2009.

of the 2009 NHTSA/UMTRI studies were used as baseline figures in the effectiveness estimates. Combining the analysis from the two studies, this research determined effectiveness rates for ESC ranged from 28 to 36 percent and from 21 to 30 percent for RSC.[12]

In May 2012, NHTSA proposed a new FMVSS which would mandate ESC on all new truck tractors with a gross vehicle weight rating (GVWR) greater than 26,000 pounds two years after the rule goes into effect. The proposal (FMVSS No. 136 Electronic Stability Control Systems on Heavy Vehicles) states that ESC systems should be tractor-based and comply with two compliance tests and four performance criteria which include: 1) Slowly Increasing Steer Characterization test; and 2) Sine with Dwell test. The proposed performance criteria are: 1) Engine Torque Reduction; 2) Lateral Acceleration Ratio; 3) Yaw Rate Ratio; and 4) Lateral Displacement. The system must also have a malfunction telltale (warning lamp) however, an On/Off switch to turn off ESC would not be allowed.

To rationalize the proposed ESC rule, NHTSA conducted a cost benefit analysis of the two RSS systems in 2012.[13] The analysis found that while RSC systems were only slightly less effective at preventing rollover crashes than an ESC system (37 to 53 percent versus 40 to 56 percent effective, respectively), they were much less effective at preventing loss of control crashes (3 percent versus 14 percent). This led to an aggregated effectiveness rate for RSC of 21 to 30 percent, opposed to a 28 to 36 percent effectiveness rate for ESC systems. In terms of the unit cost of these RSS installations, ESC technology costs an average of $1,160 per unit, while RSC averages $640; an upgrade from RSC to ESC averages $520 per vehicle. [14] The proposal also considered two alternative options: 1) requiring all new applicable vehicles to be equipped with RSC; and 2) requiring trailer-RSC for all new trailers. Alternative 1 (RSC only) was found to be more cost-effective and lower in total costs than the proposed ESC rule. However, the ESC rule generated a larger net societal benefit due to a greater number of prevented fatalities and injuries.

In summary, relevant literature shows that both RSC and ESC are viable technologies with crash reduction potential. However, ESC technology is designed to prevent a wider array of crash types and was demonstrated in research tests to avert a larger number of incidents. Research determined that effectiveness rates for ESC ranged from 28 to 36 percent and from 21 to 30 percent for RSC.[15] ESC was markedly more costly to adopt compared to RSC. The unit cost of RSC technology averaged $640, while ESC systems averaged $1,160.[16] While research found that RSC is slightly more

[12] "Effectiveness of Stability Control Systems for Truck Tractors". National Highway Traffic Safety Administration, United States Department of Transportation. Washington, D.C. 2011.
[13] "FMVSS No. 136 Electronics Stability Control Systems on Heavy Vehicles". National Highway Traffic Safety Administration, United States Department of Transportation. Washington, D.C. 2012.
[14] Ibid.
[15] Ibid.
[16] Ibid.

cost-effective than ESC, the NHTSA FMVSS proposal favors ESC over RSC as it was found to have greater societal net benefits.[17]

Given the nascent state of the technology and related data collection efforts, the underlying studies that informed the ESC FMVSS were based on controlled field tests, as opposed to empirical operational crash data. There is currently no available large-scale RSS study that has analyzed the cost effectiveness of RSC versus ESC systems based on actual truck crash data. The ATRI research presented in this report is designed to address this data gap.

3.0 DATA COLLECTION

To provide input to the 90-day public comment period associated with NHTSA's FMVSS 136 on ESC, ATRI immediately commenced collecting crash and financial data from the trucking industry. ATRI advertised its request for data through several outlets, including industry news alerts, coverage in major industry news outlets and working through manufacturers of both ESC and RSC. The data were obtained confidentially using a standardized data collection form provided by ATRI upon request. Once the respondents provided the relevant and available information, it was tabulated using spreadsheet software applications. The requested data cells included demographic information regarding industry sector, total fleet size, and fleet vehicle configurations, the number of trucks equipped with either RSC or ESC and those with neither technology. Carriers then identified the type of RSS for each truck within their fleet. Requested data also included the average per-unit cost of the purchased RSS, average annual miles per tractor, total annual number of safety incidents by type (rollover, jackknife, and tow/stuck) and average per-tractor costs for each safety incident type. If available, carriers were asked to provide these data for three calendar years. The full data request form is available in **Appendix A**. For quality management, ATRI reviewed the data for any entry errors and followed up with the respondents to address any issues or questions.

4.0 ANALYSIS

ATRI ultimately received complete crash and financial data from a total of 14 large and mid-size motor carriers. The ATRI sample included a total of 135,712 trucks, of which 68,647 were equipped with RSC, 39,529 trucks equipped with ESC, and 27,536 trucks equipped with no RSS technology.

Carriers that provided data operated primarily in the truckload (TL) sector (81.5%), followed by the less-than-truckload (LTL) sector at 10.0 percent, and specialized at 8.5 percent. These respondents skewed towards TL compared to overall industry

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[17] "FMVSS No. 136 Electronics Stability Control Systems on Heavy Vehicles". National Highway Traffic Safety Administration, United States Department of Transportation. Washington, D.C. 2012.

composition, which is estimated at 52 percent TL, and 24 percent for both LTL and specialized.[18]

As with any data collection process of this nature, the sample cannot be considered random or unbiased. A fully representative sample was not likely obtainable given the constraint of the FMVSS 136 comment period. Nevertheless, the number of trucks included in the sample data is quite large and the findings of this analysis provide valuable insight into the actual operational impacts of RSS technology on a sizeable portion of the trucking industry.

Crash Rates

To begin the RSS data analysis, it was first necessary to establish the crash rates for trucks equipped with ESC, RSC and no RSS technology. A separate crash rate was calculated for each of the three types of crashes investigated (rollovers, jackknifes, tow/stuck). Table 1 presents the crash rates from the respondent data. These rates were determined by dividing the total number of crashes in each crash type category by the total vehicle miles traveled in that category. The per-mile crash rates were adjusted to per-100-million-mile rates for ease of presentation purposes.

Table 1: Number of Crashes per 100 Million Miles Traveled

	Rollover	Jackknife	Tow/Stuck
RSC	4.22	3.49	23.67
ESC	5.60	3.89	30.77
No RSS	10.62	14.39	30.35

Comparing the crash rates of ESC-equipped trucks, RSC-equipped trucks and trucks without an RSS provides insight into the efficacy of RSC and ESC systems. While it is not possible to determine from operational data alone the degree to which an RSS system was responsible for differences in crash rates, it is reasonable to assume that crash rates for types of crashes directly addressed by RSS would be lowered by the presence of RSS technology. The data in Table 1 indicate that RSS-equipped trucks generally had considerably lower crash rates than trucks without an RSS system. More specifically, RSC-equipped trucks had a 60 percent lower rollover crash rate than trucks without an RSS system (4.22 rollovers per 100 million miles versus 10.62). ESC-equipped trucks had a 47 percent lower rollover crash rate compared to trucks with no RSS system (5.60 rollovers per 100 million miles versus 10.62).

While both types of RSS-equipped trucks had lower rollover crash rates compared to non-RSS trucks, trucks equipped with RSC experienced lower rollover crash rates than trucks equipped with ESC. This counterintuitive finding, given that ESC provides additional safety deceleration functionality over RSC, warrants further exploration. Likely, additional variables, beyond the type of RSS utilized, account for a portion of the difference in safety performance between fleets. For instance, early adopters of anti-

[18] ATA. American Trucking Trends: 2005-2006. Arlington, VA.

rollover technology had only RSC as an option, since it was first to market. Interest in the technology could be indicative of additional proactive safety practices, including stronger safety cultures, more sophisticated management oversight, better training and more stringent driver selection. The explanatory power of these confounding variables, unmeasured here, may account for the unexpected finding that RSC-equipped fleets generally experienced fewer rollovers in this study.

For jackknife crashes, both RSC and ESC had similar crash rates of 3.49 and 3.89 jackknife crashes per 100 million miles, respectively. These rates are approximately 75 percent lower than those experienced by vehicles without an RSS system (14.39 per 100 million miles). Again, it is interesting that ESC, with its increased deceleration functionality, was not found to offer increased protection against jackknife crashes. However, the inability to detect superior safety performance from ESC fleets is not unprecedented. As published in a 2011 NHTSA report revising the ESC and RSC efficacy rates, the author notes, "For LOC crashes, the revised ESC effectiveness is significantly lower than that estimated by UMTRI for the four roadway categories."[19]

Finally, tow/stuck crash rates were calculated. RSC-equipped trucks had a 22 percent lower tow/stuck crash rate compared to trucks without an RSS (23.67 tow/stuck crashes per 100 million miles versus 30.35). ESC trucks had similar tow/stuck crash rates as trucks without an RSS system (30.77 tow/stuck crashes per 100 million miles versus 30.35). This indicates that, within the sample, RSC trucks experienced fewer tow/stuck crashes per mile than both ESC trucks and trucks without RSS.

Juxtaposing the three crash types yields an overall crash rate for each configuration of truck (RSC, ESC, or no RSS technology). Within the sample data, RSC trucks experienced 31.38 crashes per 100 million miles across the three crash types. ESC-equipped trucks saw 40.26 crashes per 100 million miles. Trucks without an RSS system had an average of 55.37 crashes per 100 million miles. Overall, RSS-equipped trucks had considerably lower crash rates than trucks without an RSS system. Furthermore, this analysis also indicates that RSC-equipped trucks had lower crash rates than ESC-equipped trucks for all three crash type categories. If the crash rates calculated for the sample held true for the overall industry, it would suggest that installation of RSC across the class 7/8 trucking industry would have a greater benefit to industry and society than would installation of ESC across the large truck industry.

Crash Costs

As discussed in the literature review, crashes can vary significantly in severity and cost. To address this, ATRI's survey asked respondents to provide the number of crashes experienced by their fleet according to crash type (rollover, jackknife or tow) and the per-truck average incident costs for each type. With this information, ATRI calculated the average cost that carriers are paying per mile for each crash type on RSC-equipped trucks, ESC-equipped trucks, and trucks equipped with no RSS technology. The

[19] "Effectiveness of Stability Control Systems for Truck Tractors". National Highway Traffic Safety Administration, United States Department of Transportation. Washington, D.C. 2011.

average cost figure was derived from the actual cost carriers reported for each type of crash (e.g. rollover) among each type of truck (RSC-equipped, ESC-equipped, no RSS). The costs for each of the crash types were then aggregated among all responding carriers and divided by the total vehicle miles traveled in each truck system category (RSC, ESC, no RSS). These figures represent the actual costs carriers in the sample paid for each type of crash among trucks equipped with each type of technology. It is presented on a per-mile basis to permit exposure-related comparisons across crash categories and RSS scenarios. An example for the average rollover crash cost calculation for RSC trucks is presented step-by-step below (see Table 2). These steps were repeated for RSC jackknife costs, ESC rollover costs, ESC jackknife costs, no RSS rollover costs and no RSS jackknife costs.

Table 2: Calculating Crash Costs

Step		
1	*Aggregate RSC rollover cost:*	Number of Rollovers on RSC-equipped trucks multiplied by average rollover crash cost
2	*Aggregate RSC vehicle miles traveled:*	Number of trucks equipped with RSC multiplied by average RSC-equipped truck annual vehicle miles traveled
3	*Average RSC rollover cost per mile traveled:*	Aggregate RSC rollover cost divided by Aggregate RSC vehicle miles traveled

Table 3 displays the average cost per mile (transformed to average cost per 1,000 miles traveled for ease of display purposes). These figures represent the actual costs carriers in the sample paid for each type of crash among trucks equipped with each RSS configuration. Please note that there were not enough cost data for tow/stuck crashes to be presented in this analysis.

Table 3: Crash Cost per 1,000 Miles Traveled

	Rollover	Jackknife
RSC	$3.77	$0.54
ESC	$4.81	$0.45
No RSS	$9.58	$2.67

Similar to the crash rates calculated in Table 1, Table 3 indicates that vehicles equipped with both RSC and ESC had lower crash costs per mile than vehicles without an RSS system. While trucks without an RSS system incurred an average of $9.58 in rollover crash costs per 1,000 miles, RSC-equipped trucks only generated $3.77 in rollover costs per 1,000 miles and ESC-equipped trucks experienced $4.81 in average rollover costs per 1,000 miles.

The difference between RSC and ESC average jackknife crash costs is more subtle. Again, both RSC-equipped trucks and ESC-equipped trucks both had markedly lower jackknife costs compared to trucks without any RSS technology. However, ESC trucks had a slightly lower jackknife cost per mile compared to RSC trucks (a difference of $0.09 per 1,000 miles traveled). This may indicate that the crash severity of ESC-equipped trucks, as compared to RSC trucks, is lower for jackknife crashes.

Analyzing average RSS-related crash costs cumulatively provides insight into the overall crash cost savings that each RSS technology can provide. When rollover and jackknife costs are aggregated, RSC-equipped trucks experienced an average crash cost of $4.31 per 1,000 miles. ESC-equipped trucks generated crash costs averaging $5.27 per 1,000 miles. Trucks with no RSS technology incurred $12.25 per 1,000 miles on average. The sample data indicate that while both RSS technologies had lower crash costs than trucks with no RSS technology, RSC-equipped trucks performed better with an 18.2 percent lower average crash cost as compared to ESC-equipped trucks. Were these sample figures found to be consistent with the overall trucking industry, they would indicate that industry-wide deployment of RSC systems would lead to lower industry rollover and jackknife crash costs compared to an industry-wide deployment of ESC systems.

System Installation Cost

Another critical factor in the cost effectiveness of RSS systems is the technology cost. Based on the responses, the average cost for an RSC system was $467.18. An ESC system cost, on average, $1,180.88. This indicates that, on average, ESC technology costs were 152.8 percent higher than RSC in the sample data. Using the crash costs found in Table 3, a straightforward return on investment estimation for an RSC and ESC system can be calculated. This was performed by comparing the crash cost of RSC and ESC to a baseline, namely vehicles without any RSS technology. Table 4 presents the cost savings of RSS systems from the two types of crashes analyzed along with the breakeven point based on average system cost.

Table 4: Crash Cost Savings per 1,000 Miles Traveled compared to Non-RSS Trucks

	RSC Trucks	ESC Trucks
Baseline (No RSS Crash Cost / 1,000 mi)	$12.25	$12.25
- Average Crash Cost / 1,000 mi	$4.31	$5.27
= Crash Cost Savings / 1,000 mi	$7.94	$6.98
Average System Cost	$467.18	$1,180.88
Mileage to Breakeven Point	58,842	169,101

The calculations in Table 4 assume that RSS technology is wholly responsible for the differential in average crash costs between RSS-equipped trucks and trucks without RSS technology. There may be additional fleet-level variables, such as carrier safety culture, management practices, characteristics of routes or other factors that explain some of the differential. A more lengthy study would be needed to control for these types of potential confounding variables. However, it is important to note that many carriers that submitted data had trucks in all three classes of RSS technology (RSC, ESC, no RSS). This may partially alleviate some concerns about the impact of other variables, such as safety culture, on the data.

This preliminary analysis indicates that given the lower crash rates, lower crash costs, and lower equipment costs of RSC compared to ESC, the return on investment for RSC is more favorable than that of ESC. Carriers that choose to deploy RSC would recoup the technology installation cost after 58,842 miles per truck, compared to 169,101 miles per truck for ESC. These return on investment figures are again based on the assumptions discussed in the previous paragraph.

Previous studies have assumed that there are, on average, approximately 150,000 new heavy truck tractor sales annually, and this study utilizes this figure.[20] However, it should be noted that this figure varies year-by-year and has recently been somewhat higher. In 2011, there were 212,570 Class 7 and 8 truck sales.[21] The average annual miles traveled per truck in the sample was 100,371. Combining this information with the sample averages found in Tables 1, 3 and 4 provides an indication of the total annual benefits and costs of RSC and ESC installation. Table 5 presents this analysis. These figures assume that the sample averages are representative of the overall industry.

Table 5: Annual RSS Installation Benefits/Costs

	Full RSC Deployment	Full ESC Deployment	No RSS Deployment
Number of Rollover, Jackknife, Tow/Stuck Crashes	4,724	6,061	8,336
Aggregate Rollover and Jackknife Crash Costs	$ 64,892,307	$ 79,289,874	$ 184,427,822
Installation Cost	$ 70,076,809	$ 177,132,279	$ -

Extrapolating these figures to all new trucks produced annually, the analysis indicates that should the sample be representative of the industry, full RSC deployment would result in fewer crashes, lower total crash costs, and lower installation cost than full ESC deployment.

[20] "FMVSS No. 136 Electronics Stability Control Systems on Heavy Vehicles". National Highway Traffic Safety Administration, United States Department of Transportation. Washington, D.C. 2012.
[21] "U.S. truck sales surged in 2011". *Fleet Owner*. 19 January 2012. http://fleetowner.com/equipment/news/truck-sales-surged-0119. Accessed 7 August 2012.

5.0 CONCLUSIONS

RSS systems are relatively new to the trucking industry. Prior to the availability of empirical operational crash data from motor carriers, the trucking industry and regulatory agencies have relied on limited field tests to assess the efficacy of RSS technologies. Several studies have found that while both RSC and ESC were effective at reducing un-tripped rollover crashes, ESC was more effective at reducing loss of control crashes, thus ESC was considered to be more effective overall.

This research, while constrained by the 90-day FMVSS 136 comment period, was based on operational crash and financial data for 135,712 trucks. While there may be questions relating to the representativeness of the sample to the overall truck population, the sample does consists of a relatively large number of class 7/8 trucks from more than a dozen large and medium-sized carriers. Moreover, the validity of this analysis is supported by new FMCSA-sponsored research that reveals similar rollover crash rates among RSC-equipped vehicles (i.e. close to 4 crashes per million VMT).[22]

Contrary to findings in several earlier studies, this analysis of operational data indicates that, for some fleets, RSC technology may be more effective, and cost-effective, at reducing rollover, jackknife and tow/stuck crashes than ESC technology. In the sample data, trucks equipped with RSC had lower average crash rates than trucks equipped with ESC (31.38 rollover, jackknife and tow/stuck crashes per 100 million miles versus 40.26 crashes per 100 million miles, respectively). Furthermore, the research found that RSC-equipped trucks incurred lower average crash costs than ESC-equipped trucks ($4.31in rollover, jackknife and tow/stuck crash costs per 1,000 miles versus $5.27 per 1,000 miles, respectively). The research also found that ESC technology is 152.8 percent more expensive, on average, than RSC technology ($1,180.88 per unit versus $467.18 per unit, respectively). This study definitively finds that, for the industry data sample used in this analysis, RSC technology is more effective than ESC technology at preventing rollover, jackknife, and tow/stuck crashes, thus providing greater benefit to society and carriers with markedly lower installation costs.

If the calculations derived from this data sample are consistent with the industry as a whole, this research would indicate that industry-wide installation of RSC would result in fewer rollover, jackknife and tow/stuck crashes compared to an industry-wide installation of ESC. Furthermore, an industry-wide installation of RSC would subject the trucking industry to lower rollover and jackknife crash costs. Finally, a full deployment of RSC would cost far less than a full deployment of ESC. Overall, RSC would provide greater benefit to society and industry through fewer crashes and lower crash costs compared to ESC, while doing so at a considerable implementation discount since ESC was found to be 152.8 percent more expensive based on the sample data analyzed in this study. To fully understand the impact of RSS systems on the trucking industry, further research into the efficacy of RSS technology using operational truck data is recommended.

[22] Kwan, Q. "Commercial Motor Vehicle (CMV) Industry Real World Experience with Onboard Safety Systems." Presented at the 2012 Transportation Research Board's Annual Meeting, January 2012.

APPENDIX A

Roll Stability Control vs. Electronic Stability Control Cost-Benefit Effectiveness Analysis

Requested Data Elements

The American Transportation Research Institute (ATRI) is requesting data from motor carriers related to the use of stability control systems on large trucks.

ATRI's Research Advisory Committee hypothesized that, while ESC has more crash mitigation sensors than RSC systems, the higher per-unit cost of ESC may not make it as "cost-effective" as RSC.

This research is intended to inform responses to the Notice of Proposed Rulemaking from the National Highway Traffic Safety Administration (NHTSA), which proposes to mandate ESC on all new equipment two years after the rule goes into effect.

All responses to this data request will be kept completely confidential. ATRI will only report information in an anonymized, aggregate form.

<u>For some questions (Q4, Q7, Q8) you will be asked to provide up to 3 years worth of data. Please answer all questions with the same 3 years in mind (e.g. 2009, 2010, 2011).</u>

1) What percentage of your fleet operates in the following sectors (should total 100%)?

Sector	%
Truckload	
Less-Than-Truckload	
Specialized: Tankers	
Specialized: Flatbed	
Express / Parcel Service	
Other (please specify):____________________	

2) What percentage of your fleet is comprised of the following vehicle configurations (should total 100%)?

Vehicle Configuration	%
5-axle Dry Van	
5-axle Flatbed	
5-axle Tanker	
Straight Truck	
Longer Combination Vehicles (Doubles, Triples, etc.)	
Other (please specify):_______________	

3) Is the following type of stability control system used in your fleet?

Stability Control System	Y or N
Roll Stability Control (RSC)	
Electronic Stability Control (ESC)	

4) How many trucks are equipped with a stability control system?

Data for Calendar Year	Stability Control System	# of Trucks
1. 20_____	Equipped with RSC	
	Equipped with ESC	
	Total Number of Trucks in Your Fleet	
2. 20_____	Equipped with RSC	
	Equipped with ESC	
	Total Number of Trucks in Your Fleet	
3. 20_____	Equipped with RSC	
	Equipped with ESC	
	Total Number of Trucks in Your Fleet	

5) What is the average per unit cost for a stability control system by type?

Stability Control System	Average Cost Per Unit
RSC	$
ESC	$

6) **Please list the average annual miles per tractor with and without stability control.**

Stability Control System	Average Annual Miles per Tractor
Tractors with RSC	
Tractors with ESC	
Tractors without a stability control system	

7) Please list the total annual number of safety incidents by type for tractors with and without stability control systems. Please provide these numbers, if possible, for 3 years with each year in a separate chart.

The data provided is for calendar year__________.

Safety Incident Type	For Tractors with RSC	For Tractors with ESC	For Tractors without a stability control system
Total number of **Rollovers**			
Total number of **Jackknifes**			
Total number of **Tows/Stuck**			

The data provided is for calendar year___________.

Safety Incident Type	For Tractors with RSC	For Tractors with ESC	For Tractors without a stability control system
Total number of **Rollovers**			
Total number of **Jackknifes**			
Total number of **Tows/Stuck**			

The data provided is for calendar year___________.

Safety Incident Type	For Tractors with RSC	For Tractors with ESC	For Tractors without a stability control system
Total number of **Rollovers**			
Total number of **Jackknifes**			
Total number of **Tows/Stuck**			

8) Please list the average per tractor crash cost for each safety incident type for tractors with and without stability control systems. Please provide these numbers, if possible, for 3 years with each year in a separate chart.

The data provided is for calendar year__________.

Safety Incident Type	**Average per tractor cost for each safety incident**		
	For Tractors with **RSC**	For Tractors with **ESC**	For Tractors **without** a stability control system
Rollovers			
Jackknifes			
Tows/Stuck			

The data provided is for calendar year____________.

Safety Incident Type	**Average per tractor cost for each safety incident**		
	For Tractors with **RSC**	For Tractors with **ESC**	For Tractors **without** a stability control system
Rollovers			
Jackknifes			
Tows/Stuck			

The data provided is for calendar year____________.

Safety Incident Type	**Average per tractor cost for each safety incident**		
	For Tractors with **RSC**	For Tractors with **ESC**	For Tractors **without** a stability control system
Rollovers			
Jackknifes			
Tows/Stuck			

Please return to ATRI at atri@trucking.org or fax to (770) 432-0638