Analysis of
Benefits and Costs
of
Roll Stability Control Systems
for the Trucking Industry

U.S. Department of Transportation
Federal Motor Carrier Safety Administration

February 2009

FOREWORD

The goal of the Federal Motor Carrier Safety Administration (FMCSA) is to reduce the number and severity of commercial motor vehicle (CMV) crashes. Over the last several years, FMCSA has collaborated with the trucking industry to test, evaluate, and encourage the deployment of effective onboard safety systems for CMVs to enhance the safety of all roadway users.

The purpose of this document is to provide economic benefits, expected costs, and industry returns on investment for roll stability control systems. Verification of the costs and benefits of safety systems is critical to facilitate voluntary acceptance of these systems in the motor carrier industry. To ensure deployment, systems must be cost-effective investments that meet user needs. Confidence in onboard safety systems' ability to reduce CMV-involved fatalities and injuries is a necessary precondition for acceptance and adoption of these systems.

The benefit-cost analysis presented in this document covers financial metrics, such as return on investment and payback periods, for the end users of the onboard safety systems—commercial motor carriers. This document intends to augment, rather than supersede, previous analyses that have focused on onboard safety systems.

The development of this analysis required the solicitation and collection of data sets from multiple industry resources. This information collection is covered by the OMB and Paperwork Reduction Act exemption for ITS-related surveys, questionnaires, and interviews defined in Section 5305, Title V, Subtitle C, paragraph (i) (2) of the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users of 2005, which states that "Any survey, questionnaire, or interview that the Secretary considers necessary to carry out the evaluation of any test or program assessment activity under this subchapter shall not be subject to chapter 35 of title 44."

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16. Abstract

The Federal Motor Carrier Safety Administration's (FMCSA) safety goal is to reduce the number and severity of commercial motor vehicle fatalities and crashes. During the last several years, FMCSA has collaborated with the trucking industry to test, evaluate, and facilitate the deployment of several onboard safety systems for commercial motor vehicles to increase the safety of all roadway users.

The purpose of this report is to evaluate costs and benefits for industry associated with Roll Stability Control (RSC) systems that can reduce large-truck rollovers.

The analysis described herein indicates that RSC systems on combination vehicles will help to prevent rollovers caused by excessive speed in a curve. Motor carriers purchasing this technology will likely see net positive returns on investments within a 5-year product lifecycle for the crash types and operating scenarios described in this report.

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Unclassified	**Unclassified**	**69**	**N/A**

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	Millimeters	mm
ft	feet	0.305	Meters	m
yd	yards	0.914	Meters	m
mi	miles	1.61	Kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	Hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	Milliliters	ml
gal	gallons	3.785	Liters	l
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		MASS		
oz	ounces	28.35	Grams	g
lb	pounds	0.454	Kilograms	kg
T	short tons (2000 lbs)	0.907	Megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celsius Temperature	°C
		ILLUMINATION		
fc	foot-candles	10.76	Lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	pound-force	4.45	Newtons	N
psi	pound-force per square inch	6.89	Kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	Inches	in
m	meters	3.28	Feet	ft
m	meters	1.09	Yards	yd
km	kilometers	0.621	Miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	Acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
ml	milliliters	0.034	fluid ounces	fl oz
l	liters	0.264	Gallons	gal
m^3	cubic meters	35.71	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	Ounces	oz
kg	kilograms	2.202	Pounds	lb
Mg	megagrams	1.103	short tons (2000 lbs)	T
		TEMPERATURE (exact)		
°C	Celsius temperature	1.8 C + 32	Fahrenheit Temperature	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	pound-force	lbf
kPa	kilopascals	0.145	pound-force per square inch	psi

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with section 4 of ASTM E380.

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ACRONYMS

ABS	Anti-Lock Braking System
ATRI	American Transportation Research Institute
BCA	Benefit-Cost Analysis
BLS	U.S. Department of Commerce, Bureau of Labor Statistics
COG	Center of Gravity
CMV	Commercial Motor Vehicle
ESC	Electronic Stability Control
FMCSA	Federal Motor Carrier Safety Administration
FOT	Field Operational Test
GES	General Estimates System
HAZMAT	Hazardous Materials
IVI	Intelligent Vehicle Initiative
MACRS	Modified Accelerated Cost Recovery System
NASS	National Sampling Automotive System
NHTSA	National Highway Traffic Safety Administration
OEM	Original Equipment Manufacturer
OSS	Onboard Safety System
PAR	Police Accident Report
PDO	Property Damage Only
RA&C	Roll Stability Advisor and Controller
RSA	Roll Stability Advisor
RSC	Roll Stability Control
USDOT	U.S. Department of Transportation
VMT	Vehicle Miles Traveled

EXECUTIVE SUMMARY

INTRODUCTION

The goal of the Federal Motor Carrier Safety Administration (FMCSA) is to reduce the number and severity of commercial motor vehicle (CMV) crashes. Over the last several years, FMCSA has collaborated with the trucking industry to test, evaluate, and encourage the deployment of several onboard safety systems (OSS) for CMVs in an effort to enhance the safety of all roadway users.

As part of an ongoing FMCSA effort to encourage voluntary adoption of onboard safety systems, this analysis builds on previous field operational testing by refocusing benefit-cost assessments from more general societal impacts to targeted motor-carrier-industry outcomes, since motor carriers are the end-users responsible for investment and deployment of OSS. The purpose of this benefit-cost analysis (BCA) is to provide return on investment information to the motor carrier industry in support of future decisions to purchase stability control systems. According to the motor carrier industry, verifying associated costs and benefits of safety systems is critical for deployment, since these systems must prove to be beneficial, cost-effective investments that meet the users' needs.

This document presents the BCA for roll stability control (RSC) systems from a motor carrier's perspective. However, other industry stakeholders such as insurance companies, vendors, and risk managers can equally apply the calculations to their own internal assessments and programs.

TECHNOLOGY DESCRIPTIONS

Stability control systems include sensors that monitor vehicle dynamics and estimate the stability of a vehicle based on its mass and velocity. RSC and electronic stability control (ESC) systems represent two different types of automated stability control systems that actively reduce the vehicle's throttle and apply its brakes to decelerate the vehicle if a high rollover risk or instability threshold is detected. RSC systems address roll instability, while ESC systems address both roll and yaw instability (loss of vehicle directional control). The present analysis focuses on the costs and benefits of the RSC system. A future BCA will focus on the ESC systems, after further information about its added benefits and efficacy has been determined through ongoing analyses at the U.S. Department of Transportation (USDOT).

BENEFIT-COST ANALYSIS

For this BCA, the potential benefit, in terms of crash cost avoidance, was measured against the purchase, installation, and operational costs of RSC systems in motor carrier operations. The primary data source for benefits came from information provided by insurance companies and motor carriers on actual expenses incurred in a CMV crash. As a result, this assessment incorporates actual motor-carrier-based benefit-cost data.

The methodology for this analysis was based on estimates of crash cost avoidance for the primary types of crashes that can be addressed by the RSC systems on combination vehicles. RSC system benefits were based primarily on reducing the occurrence of large-truck rollovers caused by excessive speed in a curve. To obtain a measure of crash cost avoidance, the number of rollovers that the technology is estimated to prevent each year per vehicle miles traveled (VMT) was determined. Next, using information provided by motor carriers, insurance companies, legal experts, and others, the actual crash costs paid by the motor carrier industry was determined for rollovers. As a result, trucking companies can use this cost information as a basis for juxtaposing and evaluating the potential crash avoidance benefits of RSC systems with the purchase and operational costs of these technologies.

The motor carrier crash costs that may be fully or partially avoided by the use of RSC systems include:

- Labor Costs
  - Recruitment
  - Training
  - Testing
  - Hiring and orientation
- Workers' Compensation Costs
- Operational Costs
  - Cargo damage due to crash
  - Cargo delivery delays
  - Loading and unloading cargo
  - Towing, inventory, and storage
- Property Damage and Auto-Liability Costs
- Environmental Costs
  - Fines
  - Clean-up
- Legal Costs
  - Court costs
  - Legal fees and costs
  - Out-of-pocket settlements for injuries and fatalities

SUMMARY OF FINDINGS AND CONCLUSIONS

In order to apply the costs specifically to motor carriers, this analysis was based on the assumption that these crash costs would be incurred by motor carriers with deductibles at or above total crash costs, or by self-insured motor carriers. However, other industry stakeholders such as insurance companies, vendors, and risk managers can equally apply the calculations to their own internal assessments and programs. The following findings and conclusions were derived from the benefit-cost analysis.

Using efficacy rates of 37 percent and 53 percent derived from a simulations and industry input (see Section 3.1.2), it was estimated that between 1,422 and 2,037 combination vehicle rollover crashes in curves could be prevented through use of the RSC. Based on the average estimates of the crash cost elements listed in the previous section, a property-damage-only (PDO) rollover crash would cost $196,958, an injury rollover crash would cost $462,470, and a fatal rollover crash would cost $1,143,018. These avoided costs or benefits of the RSC system were based on a typical or median-cost incident; therefore, they should be interpreted as approximations of expected values that could be reasonably quantified.

Crash avoidance costs based on VMT and expected crash reductions resulting from deployment of RSC systems were calculated for annual VMT values of 80,000, 100,000, 120,000, 140,000, and 160,000 miles. However, the research relied heavily on documented annual average VMT of 100,000 to 110,000 for class 6–8 trucks used in a variety of operational environments.

The technology and deployment cost estimates for the RSC systems included the technology purchase price (with and without the added cost of traction control), maintenance costs, and the cost of training drivers in the use of the technology. Purchasing the technology with or without financing was also considered in these costs, as well as Federal tax savings due to depreciation of the stability control system equipment. These total costs ranged from approximately $440 to $866.

The net present values of the RSC systems were computed by discounting future benefits and costs for the values using discount rates of 3 and 7 percent. Discounting benefits and costs transforms gains and losses occurring in different time periods to a common unit of measurement. These values were calculated over the first five years of deployment, since beyond five years, estimates of product lifecycles are speculative. When the anticipated present value costs and benefits of the RSC systems were compared, the benefits of using the system over a period of five years outweighed the costs associated with purchasing the systems at each efficacy rate and for each VMT category. For every dollar spent, carriers get more than a dollar back in benefits that could be quantified for this analysis, ranging from $1.66 to $9.36 based on different VMTs, system efficacies, and technology purchase prices.

Payback periods were also calculated to estimate the length of time required to recover the initial investments made for the RSC systems. These payback periods ranged from six to 30 months, depending on the different VMT, system efficacy estimates, and technology purchase costs.

Since certain industry segments will experience different costs and benefits due to differences in operating practices, a sensitivity analysis was performed to show some of these differences for small carriers and high-value cargo carriers.

It was important to consider small carriers separately from large carriers due to discrete differences in their financial and operating environments. For instance, small carriers are unlikely to be self-insured; therefore, out-of-pocket costs per crash will initially be much lower for small carriers. Since the median deductible for a motor carrier will fall in the $5,000 to

$50,000 range, these low and high deductibles were considered as part of the benefit and cost analysis.

Based on the overall probability of involvement in a rollover crash, small carriers that have lower deductibles, such as $5,000 per truck, may not achieve a break-even point— a dollar or more of benefits for each dollar spent on financing the technology—in the first five years. However, as the number of crashes and/or their severity increases, insurance premium costs will increase until the carrier's insurance costs equal or exceed the investment costs of the RSC system; or the carrier is dropped altogether by the insurance provider. For this reason, an investment in the technology may still be considered judicious for added protection against rising insurance costs. In addition, avoiding the indirect costs of crashes, such as impact on safety ratings, public image, and employee morale, can add to the benefits of purchasing onboard safety systems.

1. INTRODUCTION

The safety goal of the Federal Motor Carrier Safety Administration (FMCSA) is to reduce the number and severity of commercial motor vehicle (CMV) crashes. Over the last several years, FMCSA has collaborated with the trucking industry to test, evaluate, and encourage the deployment of effective onboard safety systems (OSS) for CMVs in an effort to enhance the safety of all roadway users.

FMCSA is now promoting voluntary adoption of these systems in trucking fleets by initiating steps to work closely with the trucking industry. Stability control systems are commercially available onboard safety technologies designed to prevent rollover and loss-of-control crashes.

In 2003, the U.S. Department of Transportation (USDOT) published an independent evaluation of the Freightliner Intelligent Vehicle Initiative (IVI) Field Operational Test (FOT) (Battelle 2003). The report included a societal-benefit-cost analysis over a 20-year period of deployment for a stability system designed to prevent rollovers caused by excessive speed in a curve. A wide range of societal costs were included, such as the lost productivity of commuters caught in traffic jams caused by truck crashes, or costs of police, fire, and emergency rescue responses to crashes. While succeeding in identifying the societal costs that could be linked to CMV crashes, the study did not focus on the direct costs incurred by commercial motor carriers. The avoidance of the societal costs indicated here does not immediately translate into bottom-line cost savings for motor carriers considering purchasing onboard safety systems.

As part of an ongoing FMCSA effort to encourage voluntary adoption of stability control systems, this benefit-cost analysis builds on the previous FOT by changing the focus of the benefit-cost analysis from general societal costs to the costs incurred by the motor carrier industry—the end-users who are responsible for investment and deployment of the technology. The purpose of this benefit-cost analysis (BCA) is to provide critical cost and return-on-investment information to the motor carrier industry in support of future decisions to purchase stability control systems. The motor carrier industry has confirmed that verifying associated costs and benefits of safety systems is critical to spur deployment, since these systems must prove to be beneficial, cost-effective investments that meet the users' needs.

1.1 TECHNOLOGY DESCRIPTIONS

Stability control systems include sensors that monitor vehicle dynamics and estimate the stability of a vehicle, based on its mass. Roll stability control (RSC) and electronic stability control (ESC) systems represent two different types of automated stability control systems that actively reduce the vehicle's throttle and apply its brakes to decelerate the vehicle if a high rollover risk or instability threshold is detected. RSC systems address roll instability, while ESC systems address both roll and yaw instability. Crashes caused by excessive speed in curves and loss of vehicle control are typical instability situations that are addressed by both RSC and ESC technologies. This document provides the analytical framework and findings of the benefit-cost analysis for RSC systems from a motor carrier perspective. A future BCA will focus on the ESC systems, once further information about its added benefits and efficacy has been determined through ongoing analyses at the USDOT.

1.1.1 Roll Stability Control Systems

An RSC system includes wheel speed sensors and a lateral accelerometer to determine critical rollover thresholds, so that it can engage anti-lock braking system (ABS), traction control, and roll control to prevent rollovers due to lateral forces. As shown in Figure 1, most rollovers caused by excessive speed in a curve occur when the vehicle's overturning moment due to lateral acceleration (F_{lat} at *COG*) and outward displacement (*G*) of the center of gravity (*COG*), exceeds the vehicle's tires' opposing forces (F_{lat} between the tires and road). A high load center of gravity height (h_{cog}) is the primary factor leading to low rollover thresholds when vehicles are affected by lateral forces.

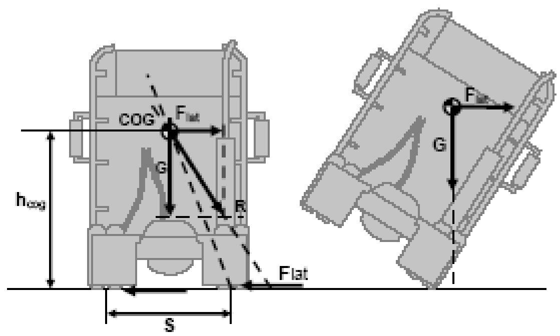

Figure 1. Forces on a Vehicle in a Steady-State Turn

Currently available RSC systems continuously monitor lateral forces while the vehicle is in operation. An electronic control unit within the RSC system processes the information received from the onboard sensors to detect the risk of a rollover. RSC systems automatically reduce the throttle and apply engine and foundation brakes to counteract the tendency of a vehicle to roll over because of excessive speed in a curve. This technology reduces the potential for rollovers due to excessive lateral acceleration.

Other factors influencing a vehicle's stability include the load offset, road friction, vehicle suspension stiffness, and vehicle track distance between tires. Also, the sloshing movement of liquid in a partially filled cargo tank can particularly affect its stability as the vehicle travels along a curve, since the liquid in the tank can move in a direction opposite to that in which the vehicle is steered.

1.2 FREIGHTLINER FIELD OPERATIONAL TEST

The 2003 Freightliner FOT evaluation showed that a previous version of a stability system, the roll stability advisor and controller (RA&C), could effectively reduce rollovers and roadway departure crashes. The tested RA&C included two major components:

1. The roll stability advisor (RSA)—a passive system that communicates with the driver about recent rollover conditions after the events have occurred, with the objective of changing driver performance in future similar driving situations.
2. The RSC system—an active system that interacts with the vehicle to prevent a rollover caused by excessive lateral acceleration.

In the FOT, the version of the RSC system that performed autonomous braking used only the engine retarder, often referred to as a “Jake Brake,” which uses engine compression to slow the vehicle. Meritor WABCO, the RSC system manufacturer involved in the FOT, recognized that greater safety benefits could be realized by engaging the service/foundation brakes instead of using only the engine retarder. The foundation brakes provide faster and more positive braking forces, potentially increasing the system’s effectiveness in reducing rollover crashes. As a result, Meritor WABCO subsequently developed an improved RSC system that uses foundation brakes to slow the vehicle in response to detected critical events.

To estimate the effectiveness of the improved RSC system without conducting another FOT, a computer simulation tool was used to model how a tractor pulling a cargo tank semi-trailer, similar to the vehicles in the FOT, would behave if it were equipped with the improved RSC system in situations or driving conflicts similar to those observed in the FOT (FMCSA 2006b). Using the simulation, the currently available RSC system was estimated to prevent approximately 53 percent of the rollovers resulting from excessive speed in curve.

1.3 BENEFIT-COST ANALYSIS ASSUMPTIONS

Large-truck crashes often involve a complex series of critical events and factors, many of which hold the potential to be mitigated through the use of OSS. However, crash reduction is also dependent on motor carrier factors which may not be directly addressed by OSS, such as operational characteristics, back-room safety initiatives, motor carrier safety “culture,” and driver selection, training, and management practices (Short et al. 2007). As a result of varying degrees of success in addressing these motor carrier factors, the levels of crash reduction and cost savings from the implementation of RSC systems may deviate from the projected values in this analysis.

The trucking industry is a broad collection of many industries, each with operating characteristics as diverse as the customers they serve. Segmentation of the trucking industry is often based on the size of fleets, vehicle configurations, geographic range of operations, and commodities hauled. Usually one characteristic is insufficient to describe a particular segment, and a combination of characteristics is necessary to accommodate the variety of operations. In an effort to address the tremendous diversity found within the trucking industry, real-world information and data for this study were provided by carriers operating in a wide range of industry segments, yet these data may not be representative of the unique characteristics of every motor carrier. Some specific areas of diversity among carriers—such as VMT, fleet size, and high-value cargo hauling—were given special attention in order to take account of factors that may have a disproportionately large impact on the costs associated with crashes.

Lastly, the commercial vehicle population is comprised of a wide variety of vehicle types and uses. At a general level, two types of vehicles are predominant, combination vehicles (tractor-trailers) and straight trucks. These two types of vehicles have very different operating characteristics. In general, straight trucks tend to be used in localized settings, generally providing pick-up and delivery services to customers within a 50–100-mile radius of their base of operations. Combination vehicles are more often used in regional and long-distance applications, accounting for approximately 30 percent of all commercial vehicles, and 65 percent of commercial VMT. Due to high mileage exposure and severity of crashes, combination trucks have the highest average crash costs per vehicle over the operational life of the vehicle (Wang et al. 1999).

An analysis of the data in FMCSA's Large-Truck Crash Causation Study (FMCSA 2006a) found that the predominant truck configuration (approximately 90 percent of cases) in rollover crashes addressed by RSC systems was the combination vehicle. In addition, the combination vehicle was the type of truck used in the Freightliner FOT and RSC system simulation. As a result of these findings, this analysis is focused on the benefits of RSC technologies for combination vehicles, which are typically less stable than single-unit straight trucks. While these and other OSS analyses sponsored by the USDOT to date indicate that combination trucks are likely to benefit most from RSC systems, other types of commercial motor vehicles, such as straight trucks, may also realize safety benefits from these stability systems.

2. BENEFIT-COST ANALYSIS STEPS

This section outlines the steps estimating costs and benefits of stability systems for motor carriers that are considering investing in OSS technologies. **Appendix A** provides details on all data sets used in the benefit-cost analysis. The total benefits of deploying stability systems include direct savings from preventable crashes and indirect benefits from the overall improvement in fleet safety. The costs of deploying stability systems include the initial capital investments required for technology purchases, as well as training and maintenance costs.

2.1 BENEFITS IN TERMS OF CRASH AVOIDANCE

Step 1: Estimate Crashes Preventable by the RSC Systems

Crash data in the General Estimates System (GES) were used to estimate the number of combination vehicle rollovers with pre-crash movements on a curve that could be reduced using vehicle stability systems over a five-year period, from 2001 through 2005. These data were used to estimate the costs for rollovers in a curve involving property damage only (PDO), for crashes involving injuries, and for those involving fatalities. Then, using information from both motor carriers and the test simulations, efficacy rates were calculated and used to estimate the portion of these crash types that could be preventable by RSC systems.

Step 2: Estimate the Crash Costs for the Crashes Preventable by RSC Systems

Crash costs were derived from a combination of motor carriers, insurance companies, legal firms, a review of large-truck statistics; and expert opinion. In general, these costs related to the following six major areas:

- Labor costs, including recruitment, training, testing, hiring, and orientation
- Workers' Compensation costs
- Operational costs, including post-crash costs, cargo damage, towing, inventory, and storage costs
- Property damage costs
- Environmental costs
- Legal costs, including attorney fees and settlement costs for injuries and fatalities

Next, the total crash costs for the types of crashes preventable by RSC systems were determined. These costs were totaled to determine a per-crash cost estimate for crashes preventable by RSC systems of varying degrees of severity—PDO, injury, or fatality.

Step 3: Estimate Crash Exposure and Costs Based on Vehicle Miles Traveled and Expected Crash Reduction

While the analysis in Step 1 provides information on the numbers of truck crashes preventable by RSC systems, and Step 2 provides estimates for the costs of those crashes, motor carriers need to know the cost-reduction value for the avoided crashes that they can expect through the use of the RSC systems. As a result, this step involves estimating crash avoidance costs based on vehicle miles traveled (VMT) and expected crash reduction resulting from deployment of RSC systems. To address variance in the average vehicle miles traveled by carriers in different operating conditions, the crash costs were calculated for annual VMT values of 80,000, 100,000, 120,000, 140,000, and 160,000 miles. The research relied heavily on documented annual average VMTs of 100,000 to 110,000 for class 6–8 trucks used in a variety of operational environments.

2.2 TECHNOLOGY AND DEPLOYMENT COSTS

Step 4: Estimate the Technology and Deployment Costs

The technology and deployment cost estimates for the RSC systems included the technology purchasing price, maintenance costs, and the cost of training drivers in the use of the technology. Purchasing the technology with or without financing was also considered in these costs, as well as Federal tax savings due to depreciation of the stability control system equipment.

As shown in the Vendor and Motor Carrier Interview Guide (**Appendix B**), vendors and motor carriers were asked to provide supporting data related to technology costs and return on investment information.

2.3 BENEFIT-COST ANALYSIS CALCULATIONS

Step 5: Calculate Net Present Values of Benefits and Costs and Estimate Payback Periods

The net present values of the RSC systems were computed by discounting future benefits and costs for the values in Steps 3 and 4 using discount rates of 3 and 7 percent. Discounting benefits and costs transforms gains and losses occurring in different time periods to a common unit of measurement. These values were calculated over the first five years of deployment, since beyond five years, estimates of product lifecycles are speculative. Payback periods were also calculated to estimate the length of time required to recover the initial investments made in purchasing the RSC systems.

Step 6: Sensitivity Analysis

Certain industry segments will experience different costs and benefits due to differences in operating practices. The costs and benefits for these industry segments will fall outside of the normal scope of carrier operations used for the crash cost estimates in Step 5. Additional analyses were conducted for small carriers, as well as for carriers hauling high-value cargo.

3. BENEFITS CALCULATIONS

This section presents the first three steps in the BCA used to determine the benefits of avoiding crashes that could be prevented through the use of RSC systems.

3.1 STEP 1: ESTIMATE CRASHES PREVENTABLE BY THE RSC SYSTEMS

The first step in this benefit-cost analysis involved estimating the number of crashes annually that are potentially preventable using RSC systems. This estimate was based on crash data, simulation results, and motor carrier information.

3.1.1 Crash Data

Crash data in the GES were initially used to estimate the number of rollovers with pre-crash movement on a curve that could be prevented using vehicle stability systems on combination vehicles, over a five-year period, from 2001 through 2005 (NHTSA 2005). These data were used as the basis for estimating costs for rollover collisions involving PDO, injuries, and/or fatalities.

Table 1 provides the crash data for the different rollover-crash severity types addressed by RSC systems. The GES Accident, Vehicle, Event, and Person files were used to determine the total number of crashes included in the analysis for a five-year period. The annual crash data are presented in **Appendix C**. Since GES is a probability-based, nationally representative sample of all police-reported fatal, injury, and property-damage-only crashes, the data from GES yield national estimates, calculated using a weighting procedure (NHTSA 2002). Within GES, the estimated number of crashes for the type described in a record is given by the “Weight” variable. The GES Vehicle and Person files were used to count the number of large-truck rollover crashes resulting in fatality, injury, or PDO. Next, the weighted numbers of crashes in each category were summed and divided by 5 (five years) to provide a mean annual number of crashes categorized by severity.

Table 1. Mean Annual Number of Combination Vehicle Rollovers in a Curve by Crash Severity, 2001–2005

PDO Crashes	Injury Crashes	Fatal Crashes	Total
1,626	2,079	137	**3,842**

According to the GES data for 2001–2005, an average of 2,079 injury and 1,626 PDO rollovers occurred involving combination trucks with a pre-crash movement of negotiating a curve. Additionally, an average of 137 fatal rollover crashes occurred. It should be noted that RSC may also prevent other types of crashes involving excessive lateral acceleration in certain evasive maneuvers, such as double lane changes, but efficacy of the RSC in other situations was undetermined at the time of this analysis.

3.1.2 Efficacy of RSC Systems

While the crashes presented in Table 1 represent the average total number of the potential types of crashes preventable by RSC systems, these technologies are not likely to prevent all of these crashes. For example, RSC systems do not typically prevent crashes that are initiated by major vehicle mechanical failures, such as faulty brakes, steering loss, or tire blowouts, which may have been included in this data set. Other types of crashes that would most likely not be preventable by these systems include those caused by precipitating events, such as when a truck impacts a barrier, trips over a curb, or falls over an overpass. If another vehicle struck the truck or suddenly cut in front of the truck so that a stability system would not have time to activate, the crash would likely not be prevented by an RSC system. Furthermore, if the truck was traveling at an excessively high speed for roadway conditions, the system might not decelerate the vehicle enough to prevent the rollover. Finally, these systems would have limited effectiveness in the type of rollover that occurs when a truck drifts off the roadway or strikes another vehicle because the truck driver is incapacitated, seriously ill, or unconscious.

Efficacy rates or crash prevention rates represent the percentage of crashes that RSC systems would have a high probability of preventing. Using information from simulations and motor carrier feedback, a range of efficacy rates was determined and used to estimate the portion of these types of crashes that could be preventable by RSC systems. The simulation estimated the highest efficacy rate, with the RSC system preventing 53 percent of rollovers resulting from excessive speed in a curve (FMCSA 2002b). As a result, the efficacy rates of the RSC systems for preventing rollovers caused by excessive speed in curves were assumed to be a maximum rate of 53 percent from the simulation results and a minimum rate of 37 percent from the motor carrier information, showing 39 out of 106 rollovers estimated to be preventable by RSC systems. Multiplying the number of crashes in Table 1 by these efficacy rates provides the estimated numeric range of crashes preventable by RSC systems, as shown in Table 2**.**

Table 2. Estimated Mean Annual Number of Combination Vehicle Rollover Crashes in a Curve Preventable by RSC Systems by Crash Severity, 2001–2005

RSC Efficacy	PDO Rollovers	Injury Rollovers	Fatal Rollovers	Total
37% Efficacy	602	769	51	**1,422**
53% Efficacy	862	1,102	73	**2,037**

3.2 STEP 2: ESTIMATE THE CRASH COSTS FOR THE CRASHES PREVENTABLE BY RSC SYSTEMS

The second step in this benefit-cost analysis involved estimating the cost of crashes that are likely to be preventable by RSC systems.

3.2.1 Cost Data Collection Process

To develop a comprehensive estimate of rollover crash costs, the American Transportation Research Institute (ATRI) collected cost estimates from trucking industry insurers and representative motor carrier constituents within the trucking industry. As shown in the Carrier

Interview Guide (**Appendix D**), carriers and insurers were asked to estimate their costs with respect to the following data collection cost categories, including:

- Labor costs related to replacement of drivers due to temporary and permanent driver injury, and additional labor costs incurred post-crash
- Workers' Compensation costs
- Operational costs related to cargo damage towing, inventory, and storage
- Property damage costs
- Environmental costs
- Legal costs, including attorney fees and settlement costs for injuries and fatalities

The survey respondents described how the costs associated with these categories vary depending on type of crash preventable by RSC systems. Baseline data were also received from respondents on the quantity and severity of crashes, by type, which had occurred during the last year within their operations, as well as the number of drivers who had been injured and/or replaced during that period. In addition, the Interview Guide included questions on costs by type of vehicle, cargo, and insurance (e.g., deductible levels or whether the carrier is self-insured and at what levels).

The Interview Guide design was guided by previous studies and their relevant findings—specifically, average worker replacement costs from *The Costs of Truckload Driver Turnover* (Rodriguez et al. 2000). All of the costs obtained from these interviews were assumed to be in 2007-year dollars.

As shown in Appendix D, a broad range of motor carrier fleet sizes, operational models, and characteristics were represented. In addition to motor carriers, four insurance companies, two environmental clean-up firms, four industry attorneys, and five technology vendors were interviewed in support of the crash cost data collection.

After the results from initial interviews were synthesized, follow-up interviews with additional representatives of motor carriers, insurers, and legal firms were used to validate responses and address any gaps in the data. The motor carriers were asked about the cost factors related to areas in the previously listed data collection cost categories with respect to rollover crashes, although several cost categories associated with these specific crashes do not vary by crash type.

After ranges were identified for the data collection cost categories, median costs were determined. While there was little deviation between mean and median cost calculations, occasional outliers were evident in certain categories; for instance, rare jury decisions have resulted in single-fatality settlements exceeding $10 million, but these are extremely infrequent occurrences. Since these outlying responses were not representative of the sample as a whole, and would have negatively influenced the calculation of a "typical" crash cost, median values were calculated instead. The interview respondents were also asked how the potential crash costs presented may be affected by the severity of the crash—questions such as whether the crash involved PDO, injuries, or fatalities.

3.2.2 Labor Costs

In this analysis, labor cost estimates were assumed to be specific to the replacement of the truck drivers injured or killed in crashes. Since medical insurance is a basic operating cost that covers a broad array of on-the-job and off-the-job illnesses and injuries, and generally covers all personnel working for a motor carrier, these costs were not attributed as marginal costs for crashes. However, if a driver needs to be replaced because of a fatal or injury crash, a motor carrier would incur added labor costs.

Driver replacement cost estimates related to the training, testing, hiring, and orientation activities when a new driver is brought into the organization. Training costs included any ancillary tuition, instructor costs, and team-driver costs. Testing costs included a driver background check, drug screening tests, and physicals (medical exams). Hiring costs included any bonuses and relocation costs provided to new hires. When provided by carriers, orientation costs included items such as meals and lodging expenses. Table 3 presents a breakout of these median costs per each new driver hired. These cost estimates were provided by the interviewed motor carriers and insurance companies.

Table 3. Median Driver Replacement Cost Elements Per Fatal or Injury Crash

Cost Category	Injury- or Fatal-Crash Cost
Training	$3,350
Testing	$500
Hiring	$500
Orientation	$2,650
Total	**$7,000**

3.2.3 Workers' Compensation

Workers' Compensation is designed to protect workers and/or their dependents against hardships associated with injuries or death arising out of the work environment. These employees or dependents are provided with fixed monetary awards covered under Workers' Compensation, thus eliminating the need for excessive litigation.

Employers with a certain number of employees—often four or more, but the number varies by state—are legally required to furnish Workers' Compensation coverage. Rather than purchase insurance, some employers choose to self-insure their Workers' Compensation liabilities for reasons of cost effectiveness, maintaining greater control over their claims programs, and increasing safety and loss-control management. To receive self-insured status, the employer must qualify through an application process, meet specified financial requirements, and be approved by each state's Workers' Compensation agency.

These specific costs were included in the benefit-cost analysis only when the crash resulted in a driver injury or fatality. Workers' Compensation laws provide the following benefits to an employee:

- Medical Expense—payment of cost for hospitals, doctors, medical treatment, etc.

- Disability Pay—either temporary pay while the employee is recovering, or permanent pay if the employee is unable to return to work. The amount varies, but can be as high as one-half to two-thirds of normal pay
- Vocational Rehabilitation—if the injury renders the employee unable to perform the usual duties of his or her occupation, including physical therapy and re-training to enter a new trade or business

The median Workers' Compensation claims of $62,728 for motor vehicle crashes were determined from insurance industry data. According to insurance companies, approximately 10 percent of the Workers' Compensation costs can be borne by motor carriers if they are not self-insured, and the remainder is covered by insurance, as required. In order to isolate the costs that are specific to a motor carrier, in this analysis the research assumption was made that the motor carrier is self-insured or maintains a per-crash deductible that exceeds total crash costs. However, insurers can use the same figures and outputs to understand OSS benefits and impacts from an insurer's perspective.

These labor and Workers' Compensation costs apply only when the truck driver is the party injured or killed in a large-truck crash. To accurately account for the actual labor costs associated with truck crashes, as well as the cost savings that can be expected from the use of RSC systems, labor costs were multiplied by the average number of injuries and fatalities incurred by truck drivers on a per-crash basis. As shown in Table 4, on average, one truck driver is injured per rollover crash that involves an injury, and 70 percent of truck drivers are killed in rollover crashes that involve a fatality.

Table 4. Average Annual Numbers of Truck Driver Injuries and Fatalities per Rollover Crash, 2001–2005

Crash Type	Number of Crashes	Number of Injuries in Crashes	Number of Injuries per Crash	Number of Fatalities in Crashes	Number of Fatalities per Crash
Injury Crashes	2,079	2,025	1	N/A	N/A
Fatal Crashes	137	0	0	91	0.7

Using these rates, the actual labor costs associated with injuries and fatalities per crash were calculated as shown in Table 5.

Table 5. Average Labor and Workers' Compensation Cost Elements per Rollover Injury or Fatal Crash

Cost Category	Labor Costs per Injury Crash	Labor Costs per Fatal Crash
Driver Replacement	$7,000	$4,900
Workers' Compensation	$62,728	$43,910
Total	**$69,728**	**$48,810**

3.2.4 Operational Costs

Operational costs considered in this analysis included direct costs associated with cargo damage, delivery delays, loading and unloading costs, as well as towing, inventory, storage, and other miscellaneous costs. Categories of median operational costs typically paid by motor carriers in the event of a rollover are presented in Table 6. Cargo damage costs, which can include extreme ranges relating to cargo value, included direct median damage cargo claims that occurred as a result of the crash. Cargo delivery delay costs included any penalties or reimbursements paid by the carrier as a result of late delivery. Cargo loading and unloading costs were direct expenses to the company for moving the cargo from the crash scene. Towing costs included costs for both the tractor and the trailer being towed from the crash site, in addition to inventory and cargo storage costs. Miscellaneous costs included a summation of smaller crash-related costs, such as additional communication expenses associated with shipper crash communications and any public relations costs. Additional motor carrier operational costs that could be associated with crashes such as costs for emergency supplies (cones, flares, etc.) or sending staff to the crash site were described by the interviewed carriers as typical fixed "costs of doing business" and were not included in this analysis.

Median operational costs were calculated to be approximately $28,625 for rollovers, but these total costs could vary substantially, depending primarily upon the value of damaged cargo.

Table 6. Median Operational Costs per Crash

Cost Category	PDO, Injury, or Fatal Crash Cost
Cargo damage	$15,000
Cargo delivery delays	$2,875
Loading and unloading cargo	$1,850
Towing, inventory, and storage	$8,500
Miscellaneous	$400
Total	**$28,625**

Additional operational costs that were considered for inclusion in this analysis were citations and penalties resulting from crashes. Rollovers crashes may involve fines for citations, such as driving too fast for conditions. A collection of information from state and local authorities from 10 states and seven cities indicated that the average penalty for these types of fines is approximately $140. Since violation citations are not issued in all crashes and the fines are a relatively small expense, they were not included as a cost in the analysis.

3.2.5 Environmental Costs

According to an analysis of crashes in FMCSA's Large-Truck Crash Causation Study, (FMCSA 2006a) more than 70 percent of trucks in rollover crashes that could have been addressed by stability control systems spilled cargo. These types of crashes may involve costly environmental clean-up.

According to environmental remediation companies, environmental clean-up costs tend to vary, depending on whether or not a body of water was impacted and required clean-up. Based on average invoices, the costs for a water-clean-up ranged from $500 to over $100,000 per crash, depending on the type of waterway affected. If no body of water was affected, the clean-up costs ranged from $300 to over $20,000 per crash. The variability in both ranges—water-impacted and no water-impacted—depends on what type of substance is leaked or spilled, and the amount involved.

When estimated by the carriers, out-of-pocket costs for environmental clean-up depended on the crash type, but represented actual costs to the carrier. For rollover crashes, the interviewed carriers estimated a median cost of $78,500 per crash, including fees paid to an environmental clean-up company.

In addition to these costs, a carrier may be required to pay fines for any environmental damage caused. The costs of these fines also vary based on negligence, the severity of the crash, and/or whether water was impacted. Carriers reported that the average environmental fine for a crash where no water is impacted is $4,000; the average environmental fine for a crash where water is impacted is $7,500. For this analysis, the conservative figure of $4,000 was used as the environmental fine per crash. The total environmental clean-up cost used in this analysis was $82,500 for a rollover crash.

3.2.6 Property Damage Costs

Median costs for property damage in crashes that were provided by the interviewed insurers and carriers for rollovers crashes are presented in Table 7. Infrastructure and surrounding structural damage refers to the damage from the crash to structures other than the truck, such as any repair to the environment in which the crash took place and damages to other vehicles. However, in this research, the term PDO refers specifically to the damage to the truck. These median costs were provided by the interviewed insurers and carriers for rollovers.

Table 7. Median Property Damage Costs per Rollover Crash

Cost Category	PDO, Injury, or Fatal Crash Cost
PDO to truck	$53,333
Damages caused to structures other than the truck	$2,500
Total	**$55,833**

3.2.7 Legal Costs

According to initial information collected from attorney, insurer, and carrier interviews, and separately verified by three transportation attorneys interviewed as part of this analysis, legal costs relating to court costs, attorney fees, and out-of-pocket settlements vary considerably, depending on negligence, crash type, and crash severity.

The legal fees cost category included crash reconstruction costs, expert witness fees, and fees paid to attorneys. The court costs include legal filing fees, court reporter fees, deposition fees, and other miscellaneous costs relating to filing or completing litigation. These average costs are shown in Table 8 for each type of rollover crash.

Table 8. Average Legal Fees and Court Costs per Rollover Crash

Cost Category	PDO	Injury	Fatal
Legal Fees	$20,000	$25,000	$100,000
Court Costs	$10,000	$10,000	$ 10,000
Total	**$30,000**	**$35,000**	**$110,000**

The out-of-pocket settlement costs are expenses paid to claimants, including punitive and compensatory damages. The median settlement cost per fatality is $700,000. The average settlement cost per injury was calculated by a weighted average of the percentage of the incapacitating injuries multiplied by the highest settlement cost of $500,000 for injuries in a range of settlement costs for rollovers, added to the percentage of non-incapacitating injuries multiplied by the lowest settlement cost of $25,000 for injuries in a range of settlement costs for injuries. According to the GES data, approximately 30 percent of the rollovers estimated to be preventable by RSC systems involved incapacitating injuries, while 70 percent involved non-incapacitating injuries. As a result, the weighted average cost of an injury in a rollover crash preventable by an RSC system is $167,500.

For this analysis, the costs per injury or fatality depended on the average number of injuries and fatalities in crashes preventable by the RSC systems. GES data provided the numbers of injuries and fatalities in the crashes preventable by the stability control systems, which were used to calculate the average number of injuries in injury crashes and the average number of injuries and fatalities in fatal crashes. Table 9 presents these results. A detailed summary of the numbers of injuries and fatalities per year in rollovers is provided in Appendix C.

Table 9. Average Annual Numbers of Injuries and Fatalities per Rollover Crash, 2001–2005

Crash Type	Number of Crashes	Number of Injuries in Crashes	Number of Injuries per Crash	Number of Fatalities in Crashes	Number of Fatalities per Crash
Injury Crashes	2,079	2,368	1.1	N/A	N/A
Fatal Crashes	137	89	0.7	137	1.0

Table 10 shows the median cost per injury crash and per fatal crash involving a rollover preventable by the stability systems. These results were obtained by multiplying the annual average numbers of fatalities and/or injuries per crash type in Table 9 by the respective settlement costs of $700,000 for one fatality and $167,500 for one injury.

Table 10. Average Settlement Costs per Injury and Fatal Rollover Crash

Cost Category	Injury	Fatal
Out-of-Pocket Costs per Injury	$190,784	$117,250
Out-of-Pocket per Fatality	N/A	$700,000
Total	**$190,784**	**$817,250**

3.2.8 Summary of Total PDO Crash, Injury Crash, and Fatal Crash Costs for Rollovers

Based on the average cost estimates from the previous subsections, Table 11 summarizes the major crash costs for rollovers which could be avoided through the use of RSC systems. These costs are based on a typical or average incident; therefore, they should be interpreted as approximations of typical expected values.

Table 11. Cost Estimates per Rollover Crash by Crash Severity

Cost Category	PDO	Injury	Fatal
Labor and Workers' Compensation	N/A	$69,728	$48,810
Operational	$28,625	$28,625	$28,625
Environmental	$82,500	$82,500	$82,500
Property Damage	$55,833	$55,833	$55,833
Legal Settlement	$0	$190,784	$817,250
Court Costs and Other Legal Fees	$30,000	$35,000	$110,000
Total	**$196,958**	**$462,470**	**$1,143,018**

This analysis is based on the assumption that these crash costs would be incurred by motor carriers with deductibles at the total crash cost level or motor carriers which are self-insured. By Code of Federal Regulations (49 CFR 387) requirements, all motor carriers must, at minimum, either insure their equipment for crash liability and cargo damage or demonstrate the financial capacity to cover liability and cargo damage costs for all of their trucks (USDOT 2001). FMCSA will consider and approve, subject to appropriate and reasonable conditions, the application of a motor carrier to qualify as a self–insurer, if the carrier furnishes a true and accurate statement of its financial condition and other evidence that establishes to the satisfaction of the FMCSA the ability of the motor carrier to satisfy its obligation for coverage of bodily injury liability, property damage liability, or cargo liability. In the case of a crash, it is likely that a self-insured carrier would assume all of the costs summarized in Table 11.

For a carrier that is insured through an insurance company, the carrier would pay its deductible, and the insurance company would then cover most of these costs up to the policy limit. The median deductible provided by the insurance industry representatives for a liability and cargo damage insurance policy for medium-sized to large fleets was $50,000. Within the trucking industry, larger carriers typically have larger insurance deductibles. As a result, many large carriers choose to become self-insured at high values ranging from $150,000 to $5 million.

Generally, smaller carriers have lower deductibles, typically lower than the estimated median value of $50,000. In addition, new carriers often have a deductible of less than $10,000 and pay higher insurance premiums, because the insurance companies do not have the standard three to five years' worth of historic safety and operating information to determine experience ratings and appropriate premium rates.

Due to the high cost of truck crashes, major truck insurance providers and various truck fleets indicated that premiums are a significant business expense that most fleets would like to reduce. Yet, it should be noted that it is difficult to directly attribute a standardized premium increase to a single crash, since insurance calculations are based on sophisticated insurance metrics, such as "experience rating" and "loss-pick" formulas, which consider multiple factors, including safety history, crash severity, convictions, carrier size, and safety culture. Some interviewed carriers stated that they have experienced increases of approximately 8 to 15 percent in premiums annually—independent of crash history.

3.3 STEP 3: ESTIMATE CRASH COSTS BASED ON VEHICLE MILES TRAVELED AND EXPECTED CRASH REDUCTION

While the information in Step 1 provides information on the numbers of truck crashes preventable by RSC systems, and Step 2 provides estimations of the costs of those crashes, motor carriers need to know what they can expect to save on the costs of these avoided crashes through the use of the RSC systems. As a result, Step 3 involves estimating crash avoidance costs based on VMT and expected reduction in crashes achieved by deploying the RSC systems.

The average annual truck VMT can vary dramatically, depending on the motor carrier's operations. As the average VMT per truck increase, the likelihood of a truck's being involved in a crash will increase as well: the more time on the road, the greater the exposure to risk of crash. To address the variances in the average VMT traveled by carriers in different operating conditions, the crash costs were calculated for annual VMT values of 80,000, 100,000, 120,000, 140,000, and 160,000 miles.

In determining the costs of crashes preventable by RSC systems for the various annual VMT values shown in Table 12 and Table 13, the first step involved dividing the estimated mean annual number of crashes preventable by RSC systems from Table 2 by the mean annual total number of VMT for combination trucks in the United States, averaged across years 2001–2005 of 140,285 million miles (Federal Highway Administration 2001–2005). The resulting values were multiplied by annual VMT values of 80,000, 100,000, 120,000, 140,000, and 160,000 miles. The total values in Table 12 and Table 13 provide estimates of the expected value of crash costs that can be avoided through the use of RSC systems, at different efficacy rates and VMTs. The resulting expected total costs are the sum of the probability of each possible outcome (PDO, injury, or fatal) of the crashes preventable by RSC systems multiplied by its estimated cost. Each total cost value represents the average annual amount one "expects" for the cost of each crash per vehicle at a different average VMT, with identical odds repeated many times for each VMT category.

Table 12. RSC Systems: Average Annual Crash Costs per Crash Avoided for an Average Annual VMT at 37% Efficacy

Average VMT	PDO	Injury	Fatal	Total Cost*
80,000	$68	$203	$33	$304
100,000	$85	$254	$42	$380
120,000	$101	$304	$50	$456
140,000	$118	$355	$58	$531
160,000	$135	$406	$66	$607

*Total Cost may not be equal to the summation of numbers shown for PDO, Injury, and Fatal, due to independent rounding.

Table 13. RSC Systems: Average Annual Crash Costs per Crash Avoided for an Average Annual VMT at 53% Efficacy

Average VMT	PDO	Injury	Fatal	Total Cost*
80,000	$97	$291	$48	$435
100,000	$121	$363	$59	$544
120,000	$145	$436	$71	$653
140,000	$169	$509	$83	$761
160,000	$194	$581	$95	$870

*Total Cost may not be equal to the summation of numbers shown for PDO, Injury, and Fatal, due to independent rounding.

4. COST CALCULATIONS

This section presents Step 4 in the benefit-cost analysis which focuses on determining the costs of purchasing and deploying RSC systems. The technology and deployment cost estimates for the stability systems include the technology purchasing price, maintenance costs, and cost of training drivers in the use of the technology. Purchasing the technology, with or without financing, was considered in these costs.

4.1 STEP 4: ESTIMATE THE TECHNOLOGY AND DEPLOYMENT COSTS

In the United States, Meritor WABCO and Bendix are two leading market vendors of RSC systems for large trucks. The systems are original equipment manufacturer (OEM)-installed units.

Typical RSC systems have an OEM option book price of approximately $500. Yet, ABS traction control is required for the system's operation. For one cost estimate, it is assumed that a motor carrier would purchase the traction control on the truck, regardless of the decision to use an RSC system. For the other estimate, it is assumed that traction control, at an average estimated cost of $500, would be included in the purchase of the RSC.

The costs are based on the assumption that the motor carrier has the capital available to pay the upfront cost of the technology. If a motor carrier finances the purchase of the technology, the costs will increase as shown in Table 14. These calculations are based on an average interest rate of 6.38 percent, as determined from motor carrier and banking industry interviews, and generally reflect a three-year loan period.

Table 14. Cost of RSC System, if Financed

Technology	Book system purchases Price	Year 1	Year 2	Year 3	Total
RSC	$500	$183.57	$183.57	$183.57	$550.71
RSC and Traction Control	$1,000	$367.13	$367.13	$367.13	$1,101.39

It is noteworthy that motor carriers experience Federal tax savings due to depreciation of the stability control system equipment. To determine the tax savings, a tax rate of 35 percent was used (the approximate tax rate for the highest brackets for both C corporations[*] and S corporations[†]). RSC systems installed by the OEM are assumed to be part of the truck cab. Consequently, the technology is also subject to the Federal excise tax, and a depreciable life of three years was used to determine the tax savings as shown in Table 15 (Internal Revenue

[*] A C corporation is any major corporation that is taxed under Subchapter C of the Internal Revenue Code. The income of a C corporation is subject to Federal income tax.

[†] An S corporation is any corporation that is taxed under Subchapter S of the Internal Revenue Code. An S corporation pays no Federal income taxes on profits, but instead each shareholder pays an income tax on his or her respective profits.

Service 2007). The Modified Accelerated Cost Recovery System (MACRS) is the current method of accelerated asset depreciation required by the United States income tax code. Each MACRS class has a predetermined schedule, which determines the percentage of the asset's cost which is depreciated each year. The General Depreciation Class for a three-year recovery period was used to determine the depreciation of the stability control systems. The cost of the system was multiplied by the MACRS rate for each year to determine the depreciation. Then, this value was multiplied by the tax rate of 35 percent to determine the Federal tax savings.

Table 15. Federal Tax Savings due to Depreciation of RSC System

Technology	Year 1	Year 2	Year 3	Year 4	Year 5
RSC	-$58.33	-$77.79	-$25.92	-$12.97	$0.00
RSC and Traction Control	-$116.66	-$155.58	-$51.84	-$25.94	$0.00

Since these active systems temporarily take control of vehicles and do not require driver intervention, direct driver training was assumed to be the cost for a one-time training session (per driver) of one hour at a carrier cost of $23—an estimate of the average wage for a driver plus fringe benefits. It was estimated that the training will be provided annually, because of the high driver turnover rate in the trucking industry. Interviews with motor carriers have confirmed that one hour is typically the amount of time that will be spent to train drivers. The costs of trainers, manuals, and other training materials were excluded, since they are part of a carrier's existing training budget—or may be provided by the system vendors.

Motor carriers reported in interviews that maintenance of stability control systems was minimal, and that any maintenance was considered a normal operating expense. As a result, maintenance costs for the RSC system were considered to be negligible. In Table 16, the total costs of the technology, plus the added training costs, less the Federal tax savings, are provided for both the financed and non-financed options.

Table 16. Total Costs of RSC System Deployment with and without Financing

Technology	Year 1	Year 2	Year 3	Year 4	Year 5	Total*
RSC	$464.67	-$54.79	-$2.92	$10.03	$23.00	$439.99
RSC (financed)	$148.24	$128.78	$180.65	$10.03	$23.00	$490.70
RSC and Traction Control	$906.35	-$132.58	-$28.84	-$2.94	$23.00	$765.00
RSC and Traction Control (financed)	$273.48	$234.56	$338.30	-$2.94	$23.00	$866.40

*Total may not be equal to the summation of numbers shown for each year due to independent rounding.

APPENDIX A: DESCRIPTION OF DATA SETS

National Automotive Sampling System General Estimates System (NASS/GES)

SOURCES:

GES Data Files from:
http://www.nhtsa.dot.gov/portal/site/nhtsa/menuitem.0efe59a360fbaad24ec86e10dba046a0/

GES *Analytical Users Manual, 1988–2005* from:
http://www-nrd.nhtsa.dot.gov/Pubs/AUM05.PDF

The GES is directed by the National Center for Statistics and Analysis, which is a research and development arm of the National Highway Traffic Safety Administration (NHTSA). NHTSA is an agency of the U.S. Department of Transportation responsible for reducing injuries and fatalities on America's roadways through education and research on safety standards and enforcement activity. The GES sample collects data from GES data collectors in 60 different geographic sites across the United States. These data collectors work with approximately 400 police agencies within these sites; during each visit, the data collectors collect all police traffic accident reports (PARs) and then select a sample of these reports. A NHTSA contractor codes these reports into data files, while checking for quality, validity, and consistency. According to the NASS-GES Analytical User's Manual, "GES is used to identify highway safety problem areas, provide a basis for regulatory and consumer information initiatives, and form the basis for cost and benefit analyses of highway safety initiatives" (NHTSA 2005).

The PARs that GES data files are coded from represent a probability sample of all police-reported crashes in the United States. Therefore, once the records of interest within GES are isolated, a weight must be applied to calculate estimates of national crash characteristics, including items such as the number of crashes of a specific type, or the number of injuries within that accident type. This weight is indicated by the "Weight" variable in each GES data file; this weight is "the product of the inverse of the probabilities of selection at each of the three stages in the sampling process" (NHTSA 2005).

The main limitation of using GES as a data source is that when looking at extremely specific crash types, as this analysis does, there is a possibility that a query will return a small number of records. The actual number of crashes that each record represents is given by the weight, as discussed in the previous paragraph. The more specific the query—i.e., the more variables that are constrained—the more limited the number of records returned. The data fields and variables in them that were used in this analysis are presented in Table 36.

Table 36. Name and Brief Description of GES Fields Relevant to this Study

Field Name	Variables for Rollovers
Body Type BODY_TYP (V05)	66—Truck Tractor
Movement Prior to Critical Event P_CRASH1 (V21)	14—Negotiating a Curve
Rollover Type ROLLOVER (V30N)	All types except 0—No rollover
Injury Severity INJ_SEV (P09)	0—No Injury 1—Possible Injury 2—Non-Incapacitating Injury 3—Incapacitating Injury 4—Fatal Injury 5—Injured Severity Unknown 9—Unknown—[assumed as no injury]
Person Type PER_TYPE (P3Z)	1—Driver of a Motor Vehicle 2—Passenger of a Motor Vehicle 9—Unknown Occupant

Federal Highway Statistics

Federal Highway Statistics publications are managed by the Federal Highway Administration's Office of Highway Policy Information. The Highway Statistics Series contains statistical information on a variety of highway usage topics including vehicle mileage. The highway data analyzed in the Highway Statistics Series are submitted by individual states and analyzed against previously submitted data to ensure accuracy.

The total number of vehicle miles traveled (VMT) for combination trucks in the United States, averaged across years (Federal Highway Administration 2001–2005)—namely, 140,285 million miles—is shown in Table 37.

Table 37. Average Annual VMT (millions of miles) for Combination Vehicles, 2001–2005

Truck Type	2001	2002	2003	2004	2005	Average
Combination Trucks	135,400	138,643	138,322	145,398	143,662	140,285

APPENDIX B: INTERVIEW GUIDE – MOTOR CARRIER AND VENDOR DATA ON STABILITY SYSTEM EFFICACY AND RETURN ON INVESTMENT

VENDOR INTERVIEW GUIDE

All responses will be kept confidential. We will not report any identifying information.

Name/Company:

Title:

Phone/E-mail:

1. Which rollover stability system(s) does your company provide?
   ❑ Rollover Stability Control[*]
   ❑ Electronic Stability Control[†]

2. Which types of crashes does the rollover stability system likely prevent?
   ❑ Rollovers
   ❑ Jackknifes
   ❑ Other: ____
   ❑ Other: ____
   ❑ Other: ____

3. Recognizing that price information is sensitive, please indicate a price range for the rollover stability systems you provide.

   $________________ to $ ______________

4. What is the average per-unit *installation* cost for the technology?

   $_________________

[*] Rollover Stability Control systems are active systems that automatically intervene if a high rollover risk is detected because of excessive speed in a curve.
[†] Electronic Stability Control systems are active systems that automatically intervene when there is either a high risk of rollover or yaw instability.

5. What are the average annual per-unit *ongoing* costs for the technology?

   $_________________

   a. What do these ongoing costs include?
      - ❑ Maintenance
      - ❑ Inspection
      - ❑ Other: ______________________________________

6. How many hours are suggested to train a driver to use the technology?

   ________ Hours

7. What is the estimated payback period (breakeven point) for the technology?

   ________ Years

8. Please complete the table below to indicate how effective the technology is at preventing each crash type for each vehicle configuration/trailer type.

Crash Type	Single Units	5-Axle, Single Trailers	5-Axle, Single Tank Trailers	5-Axle, Single Flat-Bed Trailers	5-Axle, Double Trailers (Vans)	Longer Combination Vehicles
Jackknife						
Rollover						
Other:______________						
Other:______________						
Other:______________						

9. Could you please provide a list of companies that currently use your product?

MOTOR CARRIER INTERVIEW GUIDE

All responses will be kept confidential. We will not report any identifying information.

Name/Company:

Title:

Phone/E-mail:

1. How is your fleet best described?
   - ❑ Private fleet
   - ❑ Truckload carrier
   - ❑ Less than truckload carrier
   - ❑ Owner/operator
   - ❑ Other, please specify: ________________________

2. Please complete the following table for your company fleet.

Truck Category	Number	Percent with Rollover Stability Control Systems Currently Installed*	Year Expected 100% Installation
Straight Trucks			
Tractors			
Trailers—Dry Vans			
Trailers—Tank Trailers			
Trailers—Flatbed			

3. What is your average length of haul?
   - ❑ 100 miles or less (local)
   - ❑ Between 100 and 500 miles (regional)
   - ❑ 500 miles or more (national)

4. Which rollover stability system(s) does your company use?
   - ❑ Rollover Stability Control†
   - ❑ Electronic Stability Control‡

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* Although it is not typical, some carriers install stability control systems separately on trailers. Please complete this column for the trailers only if you are one of these carriers.

† Rollover Stability Control systems are active systems that automatically intervene if a high rollover risk is detected because of excessive speed in a curve.

‡ Electronic Stability Control systems are active systems that automatically intervene when there is either a high risk of rollover or yaw instability.

5. Which types of crashes does the rollover stability system likely prevent?
   ❑ Rollovers
   ❑ Jackknifes
   ❑ Other: ________________________________
   ❑ Other: ________________________________
   ❑ Other: ________________________________

6. For which vehicle configurations have you experienced safety benefits (from the technology)?
   ❑ Single unit (how many axles? _____________)
   ❑ Five-axle tractor, single trailer combinations
   ❑ Five-axle tractor, double trailer (vans) combination
   ❑ Longer combination vehicles
   ❑ Tank trucks
   ❑ Flat-bed trucks

7. Recent industry data have identified the following human capital costs associated with large-truck crashes. Please complete the table below to indicate how your company's data compares to the current estimates.

Cost Category	**Short-term staff disruption**	**Cost of driver recruitment marketing**	**Training costs (i.e., school costs, instructor costs)**	**Testing costs (i.e., back-ground checks, physicals)**	**Hiring costs (i.e., bonuses, training, and relocation)**	**Orientation costs**	**Total costs**
Current Estimate	No data	No data	$3350	$500	$500	$2650	$7000
Your Estimate							

8. Including inflation, please estimate the average annual percent increase in crash costs you experience (per crash).

   _____________ %

9. Recognizing that price information is sensitive, please indicate a price range for the rollover stability systems you use.

   $____________ to $ _______________

10. What is the average per-unit *installation* cost for the technology?

    $_____________

11. What are the average annual per-unit *ongoing* costs for the technology?

$______________

a. What do these ongoing costs include?
   - ❑ Maintenance
   - ❑ Inspection
   - ❑ Other: ___________________________________
   - ❑ Other: ___________________________________
   - ❑ Other: ___________________________________

12. How many hours do you provide to train a driver to use the technology?

a. How are drivers compensated for this time?

$_____________ per hour **OR** $____________ total

13. What is the estimated payback period (breakeven point) for the technology?

_____________years

14. Had your company not invested in the safety technology, what would you have done with that money instead?
   - ❑ Invested in other technologies
   - ❑ Paid off debt or other liabilities
   - ❑ Invested the cash into some type of savings account
   - ❑ Other: _________________________________

15. What is the average interest you pay on debt? __________%
(This information will be used to determine the proper discount rate for calculating the present value cost of future crashes.)

16. Please complete the following chart for trucks that are equipped with rollover stability technologies.

Technology Type: ____

Average Annual VMT per Truck: _______________________________________

Average Number of Total Crashes Per Year: ______________________________

Crash Type	**Average Number of Crashes Per Year**	**Estimated Number of Crashes Avoided with Technology Per Year**	**Average Cost per Crash**
Rollovers			
Jackknifes			
Other*: ____________________			
Other*: ____________________			
Other*: ____________________			

* Please complete this only for other crashes that may be mitigated by the technology.

APPENDIX C: SUPPORTING DATA

This appendix contains the annual number of crashes, injuries, and fatalities for rollovers in the years 2001–2005, as presented in Table 38, Table 39, and Table 40. A note on all figures: Within GES, the weight is often a seven-digit figure, with three numbers after the decimal; therefore, the following numbers are rounded.

Table 38. Annual Number of Combination Vehicle PDO, Injury, and Fatal Rollovers with Pre-Crash Movement Around a Curve, 2001–2005

Crash Type	2001	2002	2003	2004	2005	Average
Number of PDO Crashes	1,732	1,603	1,114	1,553	2,130	1,626
Number of Injury Crashes	1,995	2,414	2,082	2,089	1,815	2,079
Number of Fatal Crashes	191	20	286	52	135	137

Table 39. Annual Number of Injuries and Fatalities for Rollovers with Pre-Crash Movement Around a Curve, 2001–2005

Crash Type	2001	2002	2003	2004	2005	Average
Injuries in Injury Crashes	2,210	2,555	2,216	2,864	1,996	2,368
Fatalities in Fatal Crashes	191	20	286	52	135	137
Injuries in Fatal Crashes	74	0	372	0	0	89

Table 40. Truck Driver Injuries and Fatalities for Rollovers with Pre-Crash Movement Around a Curve, 2001–2005

Crash Statistic	2001	2002	2003	2004	2005	Average
Number Total Injury Crashes	1,995	2,414	2,082	2,089	1,815	2079
Number Truck Driver Injuries	1,897	2,187	2,204	2,089	1,746	2025
Number Drivers Injured per Injury Crash	0.96	0.93	1.06	1.00	0.96	0.98
Number Total Fatality Crashes	191	20	286	52	135	137
Number Truck Driver Fatalities	123	20	124	52	135	91
Number Drivers Killed per Fatality Crash	0.64	1.00	0.43	1.00	1.00	0.66

APPENDIX D: COST DATA –
MOTOR CARRIER QUESTIONNAIRE AND RESPONDENT DEMOGRAPHICS

Part 1: Interview Guide is shown on the next page.

Part 2: Survey Respondent Demographics follows.

PART 1: INTERVIEW GUIDE

ATRI is currently working on a trucking industry research initiative to develop a comprehensive cost-benefit analysis of select safety technologies, including rollover stability control, forward-looking radar, and lane-departure warning systems. The purpose of this interview is to gather real-world information about the costs associated with collisions that could be prevented or reduced by these types of technologies.*

The overall goal is to determine a company's approximate costs associated with different types of accidents—in particular, rollovers, side-swipes, run-off-road, rear-end accidents, and, to a lesser extent, jackknife crashes.

Thank you in advance for your time and support on this important industry research project!

For each of the following tables, please consider an average accident of each type. Then provide the number or extent of incidents, injuries, and average cost(s) for each crash type for each metric.†

* This information collection is covered by the OMB and Paperwork Reduction Act exemption for ITS-related surveys, questionnaires, and interviews defined in Section 5305, Title V, Subtitle C, paragraph (i) (2) of the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) of 2005, which states that "Any survey, questionnaire, or interview that the Secretary considers necessary to carry out the evaluation of any test or program assessment activity under this subchapter shall not be subject to chapter 35 of title 44."

† For this Appendix content, the term "accident" is maintained to preserve the integrity of the actual survey content rendered by ATRI.

Labor Costs by Collision Type:

Cost Factors	Rollovers	Side-Swipes	Run-Off-Road	Rear-End	Jackknife
Number of accidents.					
Number of drivers injured *(per 100 accidents)*.					
Costs Associated with Permanent Injuries to Driver					
Number of accidents involving permanent injury.					
Number of drivers replaced *(per 100 accidents).*					
Costs of driver recruitment marketing.					
Training Costs *(i.e., school costs, instructor costs).*					
Testing Costs *(i.e., background checks, physicals).*					
Hiring Costs *(i.e., bonuses, training, and relocation).*					
Orientation Costs.					
Costs Associated with Temporary Injuries to Driver					
Number of accidents involving temporary injury.					
Number of drivers temporarily replaced *(per 100 accidents).*					
Costs of recruitment marketing.					
Training Costs *(i.e., school costs, instructor costs).*					
Testing Costs *(i.e., background checks, physicals).*					
Recruitment Costs *(i.e., bonuses, training, and relocation).*					
Orientation Costs.					

1. A recent study placed the average worker replacement costs for all companies at $8,234. Do you consider this number reasonable? Yes ❑ No ❑

1a. If **no**, what estimate would you consider reasonable? ____________________

2. Are there additional labor costs we have not considered? Yes ❑ No ❑

2a. If **yes**, will you please describe those costs and give estimates?

Costs	Estimates

3. Do you budget or estimate the cost of driver replacement for the upcoming fiscal or calendar year? Yes ❑ No ❑

3a. If **yes**, can you describe your process and give an estimate?_______________

4. Can you estimate the wages for relief drivers? Yes ❑ No ❑

4a. If yes, please give an estimate: ____________________________________

4b. If **yes**, are they hourly, salary, or paid by the mile?
Hourly ❑ Salary ❑ By the mile ❑

Operational Costs by Collision Type (Indicate "N/A" if not available or applicable):

Cost Factors	Rollovers	Side-Swipes	Run-Off-Road	Rear-End	Jackknife
Number of accidents involving cargo damage *(per 100 accidents)*					
Average cost of cargo damage due to accident.					
Avg. cost of secondary cargo damage *(i.e., rain, exposure to weather).*					
Avg. cost associated with cargo delay *(i.e., penalties and/or reimbursements for late delivery).*					
Additional inventory costs for storing cargo.					
Any costs associated with guarding cargo after accident.					
Avg. cost associated with unloading or loading cargo *(do not include labor costs).*					
Miscellaneous operational costs *(i.e., communications expenses, press releases, etc.).*					
Emergency supplies relating to accident *(i.e., flares, fire extinguishers, etc.).*					
Towing Costs: Tractor Trailer					

5. What are the primary commodity types your company hauls? ________________________

____

6. How do accident costs vary by the commodity type? ________________________________

____

7. Does your company calculate loss of "goodwill" when considering the costs of an accident (including employee goodwill, customer goodwill, and public goodwill)?
Yes ❑ No ❑

7a. If **yes**, can you give an estimate and describe how you calculate goodwill costs?

Estimate: ____

Calculation: ____

____

Environmental Costs by Collision Type:

Cost Factors	Rollovers	Side-Swipes	Run-Off-Road	Rear-End	Jackknife
Number of accidents involving environmental impact costs (per 100 accidents)					
Average cost of fines					
Average out-of-pocket costs for cleanup					

8. Does your company incur any other environmental costs other than the ones mentioned above? Yes ❑ No ❑

8a. If **yes**, please estimate and describe the type of costs you incur.

Costs	Estimates

Insurance Costs by Collision Type:

Cost Factors	Rollovers	Side-Swipes	Run-Off-Road	Rear-End	Jackknife
Estimates of increased per-truck premiums due to each reportable accident.					
Estimate of per-accident out-of-pocket.					
Estimate of per accident out-of-pocket costs relating to property damage (tractor and trailer).					

9. What is your average deductible per vehicle/accident? ______________________

10. Does the deductible vary by type of truck? Yes ❑ No ❑

10a. If **yes**, can you please describe and give a range for your deductibles by truck type?

____

____

11. Does the deductible vary by driver history? Yes ❑ No ❑

11a. If yes, can you please describe and give a range for your deductibles?

____

____

Legal Costs by Collision Type (per accident):

Cost Factors	Rollovers	Side-Swipes	Run-Off-Road	Rear-End	Jackknife
Average court costs.					
Legal fees.					
Average out-of-pocket settlement costs.					

12. Are there additional legal expenses we have not considered? Yes ❑ No ❑

12a. If **yes**, please estimate and describe the type of costs you incur.

Costs	Estimates

13. Will you please list the average cost of all crashes assuming self-insured?

____

PART 2: SURVEY RESPONDENT DEMOGRAPHICS

Carriers:

Carrier A: This is a large (1,000+ power units) national tank truck carrier that handles bulk commodity shipping operations, providing services to the entire continental United States. The fleet primarily consists of tank trailers and a smaller fleet of flat-bed trailers. Primary commodities are chemicals and petroleum products.

Carrier B: This is a mid-sized (100–500 power units) regional truckload carrier that operates in the eastern United States and primarily utilizes van trailers. The carrier's principal commodities include general freight and limited HAZMAT.

Carrier C: This is a small (<100 power units) specialty carrier that provides expedited freight services for customers that require high levels of safety and security, with cargo types that are extremely hazardous or sensitive in nature.

Carrier D: This is a large (1,500+ power units) refrigerated carrier with both truckload and less-than-truckload operations. Typical commodities hauled include food products, medical supplies, and consumer goods.

Carrier E: This is a very large (8,000+ power unit) transportation company that provides truckload services for shippers in the United States, Canada, and Mexico. The carrier hauls general commodities with dry vans, and also utilizes flatbeds, specialty, and un-sided trailers. The operation is both long- and short-haul. The company relies heavily on the use of independent drivers.

Carrier F: This is a large (1,200+ power units) refrigerated carrier that operates throughout the United States, Mexico, and Canada. This carrier primarily hauls food products and consumer goods.

Insurance Companies:

Insurance Carrier A: This is a large, national insurance company with an emphasis on commercial transportation accounts, and is one of the top five trucking industry insurers.

Insurance Carrier B: This is a large, national insurance company with a large diversified portfolio of coverage, which includes many larger trucking industry accounts.

Law Firms:

Law Firm A: This is a regional law firm with multiple locations throughout the Midwest employing more than 80 attorneys. The firm specializes in transportation, litigation defense, collection services, and intellectual property.

Law Firm B: This is a law firm located in the Southeast employing more than 20 attorneys who specialize in litigation and insurance law.

Law Firm C: This is a national law firm with multiple locations in the Midwest and throughout the world employing more than 100 attorneys. The firm specializes in litigation, environmental, intellectual property and real estate law.

Environmental Clean-Up Firms:

Environmental Cleanup Company A: This is an environmental clean-up firm located in the Southeast that specializes in waste removal, roll-off services, and industrial cleaning. This firm performs planned and emergency services.

Environmental Cleanup Company B: This is an environmental clean-up firm with multiple locations along the Eastern Seaboard. The firm's clean-up services range from disaster response to spill management.

APPENDIX E: ACKNOWLEDGMENTS

The Roll Stability Control Systems Benefit-Cost Analysis for Large Trucks was managed by Ms. Amy Houser of the Federal Motor Carrier Safety Administration (FMCSA). The project supports FMCSA's safety goal to reduce the number and severity of large-truck fatalities and crashes by encouraging voluntary adoption of promising onboard safety technologies by motor carriers. FMCSA's efforts include an evaluation of the costs and benefits to the motor carrier community of adopting the technologies.

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