Analysis of
Benefits and Costs
of
Lane Departure Warning 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 CMVs to enhance the safety of all roadway users.

The purpose of this document is to provide the economic benefits, expected costs, and industry return on investment for lane departure warning systems. The verification of the costs and benefits of safety systems is critical for facilitating voluntary acceptance of these systems by 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 commercial-motor-vehicle-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 Office of Management and Budget (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's) 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 lane departure warning systems that can reduce large-truck lane departure crashes.

The analysis described herein indicates that combination and single-unit vehicles with lane departure warning systems will help to prevent lane-departure crashes. Motor carriers purchasing this technology will likely see net positive returns on investments within a five-year product lifecycle for the crash types and operating scenarios described in this report.

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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

ATRI	American Transportation Research Institute
BCA	Benefit–Cost Analysis
BLS	U.S. Department of Commerce, Bureau of Labor Statistics
CMV	Commercial Motor Vehicle
FARS	Fatality Analysis Reporting System/Fatal Accident Reporting System
FMCSA	Federal Motor Carrier Safety Administration
FOT	Field Operational Test
GES	General Estimates System
HAZMAT	Hazardous Materials
IVI	Intelligent Vehicle Initiative
LDWS	Lane Departure Warning System, Systems
MACRS	Modified Accelerated Cost Recovery System
NASS	National Sampling Automotive System
NHTSA	National Highway Traffic Safety Administration
ODLD	Opposite-Direction Lane Departure
OEM	Original Equipment Manufacturer
OSS	Onboard Safety System
PAR	Police Traffic Accident Report
PDO	Property Damage Only
SDLD	Same-Direction Lane Departure
SVRD	Single-Vehicle Roadway Departure
USDOT	United States Department of Transportation
VMT	Vehicle Miles Traveled

EXECUTIVE SUMMARY

INTRODUCTION

The primary 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 facilitate 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 the previous field operational testing by changing the focus of the benefit-cost assessments from societal impacts to more targeted motor carrier industry outcomes, since motor carriers are the end-users that are responsible for investment and deployment of onboard safety systems. 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 on the purchase of lane departure warning systems (LDWS). 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 LDWS from a motor carrier 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 DESCRIPTION

LDWS are forward-looking, vision-based systems, consisting of a main unit and small video camera mounted on the vehicle's windshield, recording data about the upcoming roadway. Algorithms within LDWS interpret video images of the lane to estimate the vehicle state (lateral position, speed, heading, etc.) and the road alignment (lane width, road curvature, etc.). LDWS warn drivers of a lane departure when the vehicle is traveling above a certain speed threshold and the vehicle's turn signal is not being used to make an intended lane change or departure. In addition, LDWS notify drivers when lane markings are inadequate for detection, or when the system itself malfunctions. LDWS do not take any automatic action to avoid a lane departure or to control the vehicle; therefore, drivers remain responsible for the safe operation of their vehicles.

Types of crashes that can be prevented through the use of LDWS include:

- **Single-vehicle roadway departure (SVRD)**: Crash in which a truck departs the roadway from its lane of travel, either to the left or to the right
- **Same-direction lane departure (SDLD)**: Crash in which a truck departs its lane of travel and enters into a lane of traffic traveling in the *same direction* as the truck
- **Opposite-direction lane departure (ODLD)**: Crash in which a truck departs its lane of travel and enters into an *oncoming-traffic* lane

These lane departure crash types can include different crash outcomes, such as rollovers, head-on collisions, and sideswipes.

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 these collision warning systems in motor carrier operations. The primary data source for benefits was information provided by insurance companies and motor carriers on actual expenses incurred due to CMV crashes. 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 principal types of crashes that can be addressed by LDWS on straight trucks and combination vehicles. LDWS benefits were based on reducing the occurrence of large-truck lane departure crashes. To obtain a measure of crash cost avoidance, the number of crashes that the technology may prevent each year per vehicle miles traveled (VMT) was determined. Next, using information provided by motor carriers, legal experts, insurance companies, and others, the actual crash costs which are paid by the motor carrier industry were determined for each of the associated crash types. As a result, trucking companies can use this cost information as a basis for evaluating the potential crash avoidance benefits of LDWS compared to the purchase and usage costs of the technology.

The motor carrier crash costs that may be prevented by the use of LDWS, or whose severity may be decreased, include:

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

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 equal to 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 low and high estimates of efficacy rates ranging from 23 percent to 53 percent derived from a field test and industry input (see Section 3.1.2), it was estimated that LDWS has the potential to reduce approximately 1,069–2,463 SVRD collisions, 627–1,307 SVRD rollovers, 1,111–2,223 SDLD sideswipes, 997–1,992 ODLD sideswipes, and 59–118 ODLD head-ons. Based on the average estimates of the crash cost categories listed in the previous section, these property-damage-only (PDO) crashes range in cost from $100,150–$196,958, injury crashes are in the range of $135,096–$455,936, and fatal crashes are in the range of $885,150–$1,252,872. These avoided costs or benefits of the LDWS were based on a typical or average incident; therefore, they should be interpreted as approximations of typical expected values.

Crash avoidance costs based on VMT and expected crash reduction resulting from deployment of LDWS 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 VMTs 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 LDWS included the technology purchase, maintenance costs, and 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 LDWS equipment. These total costs ranged from approximately $765 to $866.40.

The net present values of the LDWS 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 estimates of product lifecycles are speculative beyond five years. When the anticipated present value costs and benefits of the LDWS 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 $1.37 to $6.55, 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 LDWS. These payback periods ranged from nine to 37 months, depending on the different VMTs, system efficacies, and technology purchase costs.

Since certain industry segments will experience different costs and benefits because of 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 because of 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 range of $5,000–$50,000, these low and high deductibles were considered as part of the benefit-cost analysis.

Based on the overall probability of involvement in a lane departure crash, small carriers that have lower deductibles (say, $5,000 per truck) may not achieve a breakeven 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 LDWS, 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, indirect costs of crashes, such as impacts 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 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 within trucking fleets by initiating steps to work closely with the trucking industry. Lane Departure Warning Systems (LDWSs) are one type of commercially available onboard safety technology designed to prevent crashes by warning drivers of unintended lane or roadway departures.

Through the Intelligent Vehicle Initiative (IVI), the U.S. Department of Transportation (USDOT) completed an independent evaluation of the Mack IVI Field Operational Test (FOT) (FMCSA, 2006). The report included a societal benefit-cost analysis over a 20-year period of deployment for an LDWS designed to prevent run-off-the-road 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 societal costs does not immediately translate into bottom-line cost savings for the motor carriers purchasing the OSS.

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

1.1 TECHNOLOGY DESCRIPTIONS

Fundamentally, LDWS perform three main functions:

- Detect lane markings ahead of the vehicle
- Monitor the vehicle's position in the lane
- Warn the driver when the vehicle is diverging (or beginning to diverge) from the lane without turn signal activation

Currently available LDWS are forward-looking, vision-based systems, consisting of a main unit and small video camera mounted on the vehicle's windshield, recording data about the upcoming roadway. Algorithms within LDWS interpret video images of the lane to estimate the vehicle state (lateral position, speed, heading, etc.) and the road alignment (lane width, road curvature, etc.). LDWS warn drivers of a lane departure when the vehicle is traveling above a certain speed threshold and the vehicle's turn signal is not being used to make an intended lane change or departure. In addition, LDWS notify drivers when lane markings are inadequate for detection, or when the system malfunctions. LDWS do not take any automatic action to avoid a lane departure or to control the vehicle; therefore, drivers remain responsible for the safe operation of their vehicles (FMCSA 2005).

Since LDWS are vision-based systems, their performance may be limited. LDWS do not operate at delivery points and roads where the truck travels at speeds below the minimum LDWS tracking speed, typically 35 mph. As a result, LDWS notify drivers when the system is operational, but do not provide warnings under these conditions. LDWS may be beneficial in low-visibility conditions (e.g., rain, fog, and falling snow) when lane markings are present. However, because of reflections on wet road surfaces, LDWS may occasionally be unable to detect lane markings; under these conditions, the lane-tracking indicator will show that the system is not providing warnings. When lane markings are not visible on roads covered by mud, ice, or snow, the lane tracking indicator will show that the system is inactive.

Current LDWS suppliers for the large-truck industry in the United States include Iteris, AssistWare, and Delphi. The Iteris AutoVue LDWS is shown in Figure 1. During an unsignaled lane change or roadway departure, the Iteris AutoVue system emits a left- or right-side audio warning, similar to the sound of a vehicle driving over a rumble strip. The Iteris AutoVue LDWS is offered as a factory-installed option by several original equipment manufacturers (OEMs). Other camera-based systems are the Delphi and Mobileye LDWS, which feature alert configurations including simulated rumble strips, audible tones, and haptic alerts.

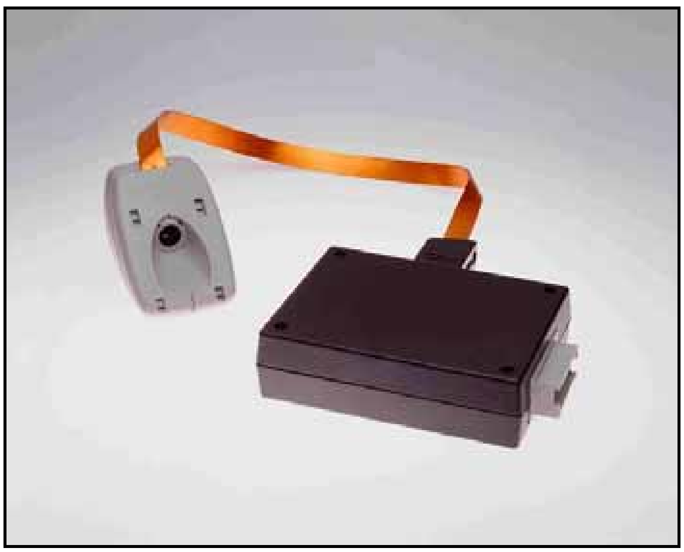

Figure 1. AutoVue LDWS

The AssistWare SafeTRAC LDWS is primarily marketed directly to fleets as an aftermarket product. As shown in Figure 2, AssistWare’s SafeTRAC system provides a graphical display depicting the vehicle’s current position in the lane, along with the lane boundary locations and types and a drift alert, which is an audible tone indicating that the truck is about to travel out of its lane or has already done so, when the driver deviates from the lane without using the turn signal. SafeTRAC also offers fleet management and driver monitoring features, such as a manufacturer-developed “alertness” score.

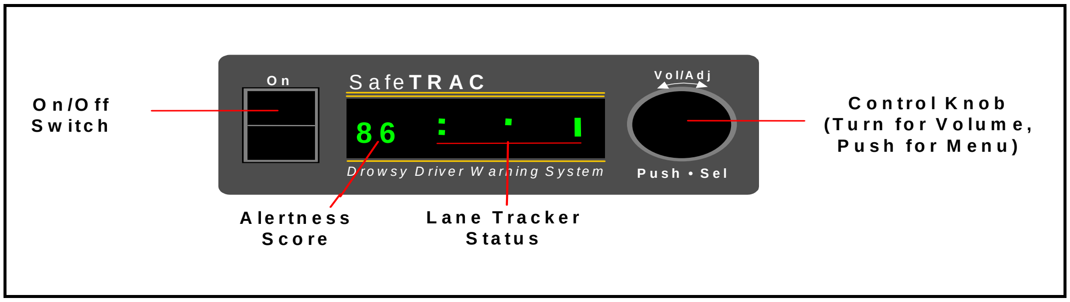

Figure 2. SafeTRAC LDWS Driver Display

1.2 MACK FIELD OPERATIONAL TEST

The Mack FOT evaluation focused on the use of LDWS to prevent single-vehicle roadway departures, also known as run-off-road crashes, and rollovers not caused by an impact with a roadside feature or other obstacle. The test results revealed that under conditions similar to those of the field test, the deployment of LDWS would result in a reduction of approximately 21–23 percent in single-vehicle roadway departure crashes and 17–24 percent reduction in rollover crashes. These findings were based upon improved driver lane-keeping behavior and a reduction in the frequency of driving conflicts in the FOT. As a result, LDWS were shown to be effective in reducing the number of situations in which a single-vehicle roadway departure or rollover crash could result, since LDWS provide advance information that the driver can use to avoid a potential hazard.

Use of LDWS also has the potential to reduce some lane departure crashes where the truck travels over the lane line. Yet, the safety benefits of the LDWS for these crash types were not evaluated in the Mack FOT, because the available FOT data were not sufficient to identify driving conflicts associated with crash types such as sideswipes. Specifically, identifying a lane departure over the lane line-related conflict requires knowledge of the presence of traffic in an adjacent lane and the speed and location of vehicles in the adjacent lane. This information could not be obtained from the data available in the FOT with adequate confidence and accuracy. However, the approximate number of these types of crashes potentially prevented by LDWS can be estimated by analyzing crash data.

The Mack FOT report included a societal benefit-cost analysis over a 20-year period of deployment for an LDWS to prevent single-vehicle roadway departure and rollover crashes. Societal costs include many factors, such as the lost productivity of workers caught in traffic congestion resulting from truck crashes, or costs of emergency response to crashes. However, avoiding these societal costs does not immediately translate into bottom-line cost savings for the motor carriers purchasing the OSS.

As a result, LDWS efficacy results from the Mack FOT were used in this report, but to determine the specific costs and benefits of the LDWS in order to aid motor carriers in making purchasing decisions, further data collection and analysis were necessary, beyond the studies previously conducted.

1.3 BENEFIT-COST ANALYSIS ASSUMPTIONS

Large-truck crashes often involve a complex series of critical events and factors, many of which can be addressed using OSS. However, crash reduction also depends on motor carrier factors which may not be directly addressed by these systems, such as operational characteristics, back-room safety initiatives and 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 realized from the implementation of LDWS may deviate from the projected values in this analysis.

The trucking industry is a broad collection of many industries, each of which has operating characteristics as diverse as the industries they service. 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 account for the variety of operations. In an effort to address the tremendous diversity found in the trucking industry, real-world information and data for this study were provided by carriers and suppliers 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 a localized setting, providing pick-up and delivery services to customers within a 50- to 100-mile radius of their base of operations. Combination vehicles are more often used in regional and long-distance applications, accounting for about 30 percent of total commercial vehicles and 65 percent of commercial vehicle miles traveled. Because of higher mileage traveled and consequent greater exposure to the risk of crashes, and because of the greater severity of crashes when they do occur, combination trucks have the highest crash cost per vehicle over the average operational life of the vehicle (Wang et al. 1999).

Since unintentional lane departures can occur along any route, many fleet types may benefit from using LDWS. These systems can be installed on any truck configuration or combination of single-unit vehicles. Yet they may be most promising for trucks that have accumulated high mileage over their operational lives and travel primarily at constant speeds greater than 35 mph.

2. BENEFIT-COST ANALYSIS STEPS

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

2.1 BENEFITS IN TERMS OF CRASH AVOIDANCE

Step 1: Estimate Crashes Preventable by LDWS

Crash data in the General Estimates System (GES) were used to estimate the lane departure crashes that can be prevented by using LDWS on large trucks over a five-year period, 2001–2005 (NHTSA 2005):

- **Single-vehicle roadway departures (SVRD):** Crashes in which a truck departed the roadway from its lane of travel, either to the left or to the right
- **Same-direction lane departures (SDLD):** Crashes in which a truck departed its lane of travel and entered into a lane of traffic traveling in the *same direction as the truck*
- **Opposite-direction lane departures (ODLD):** Crashes in which a truck departed its lane of travel and entered into an *oncoming-traffic* lane

Lane departure crash types can include different crash outcomes, such as rollovers, head-ons, and sideswipes. As a result, information from the GES data was used to estimate outcomes from different lane departure crashes. Then, using information from the Mack FOT and motor carriers, efficacy rates were determined and used to estimate the portion of these types of crashes that could be prevented by LDWS. Finally, these data were used to estimate the costs for rollover, sideswipe, head-on, and run-off roadway crashes involving property damage only (PDO), injuries, and fatalities.

Step 2: Estimate Crash Costs for Crashes Preventable by LDWS

Crash costs were derived from a combination of resources, including motor carriers, insurance companies, legal firms, a review of large-truck statistics, and expert opinion. In general, these costs related to the following 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 injury and fatality settlement costs

Next, the total crash costs were determined for the types of crashes preventable by LDWS. These costs were summed to determine per-crash cost estimates for crashes of varying degrees of severity—PDO, injury, or fatality—preventable by LDWS.

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

While the analysis in Step 1 provides information on the number of truck crashes preventable by LDWS, and Step 2 provides estimates of the costs of those crashes, motor carriers need to know what cost-reduction value of the avoided crashes they can expect from using LDWS. As a result, this step involves estimating crash avoidance costs based on VMT, and estimating the expected crash reductions from deploying LDWS. To address the variances in the average VMTs 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. However, 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 Technology and Deployment Costs

The technology and deployment cost estimates for LDWS included 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 also considered in estimating these costs, as were Federal tax savings due to depreciation of the LDWS equipment.

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 LDWS 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 determined over the first five years of deployment, since estimates of product lifecycles are speculative beyond five years. Payback periods were also calculated to estimate the length of time required to recover the initial investments made in purchasing the LDWS.

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 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 benefit-cost analysis to determine the benefits relating to the crashes that can be prevented by using LDWS.

3.1 STEP 1: ESTIMATE CRASHES PREVENTABLE BY THE LDWS

The first step in this benefit-cost analysis involved estimating how many crashes are likely to be preventable by LDWS. This estimate was based on crash data, Mack FOT results, and motor carrier information.

3.1.1 Crash Data

Crash data in the GES were used to estimate the sets of lane departure crashes preventable by LDWS over a five-year period, 2001–2005:

- **Single-vehicle roadway departures (SVRD):** Crashes in which a truck departed the roadway from its lane of travel, either to the left or to the right. LDWS can help to prevent SVRD crashes of the types that typically result in rollovers or collisions with fixed objects, as shown in Figure 3 (NHTSA 2005, 88).

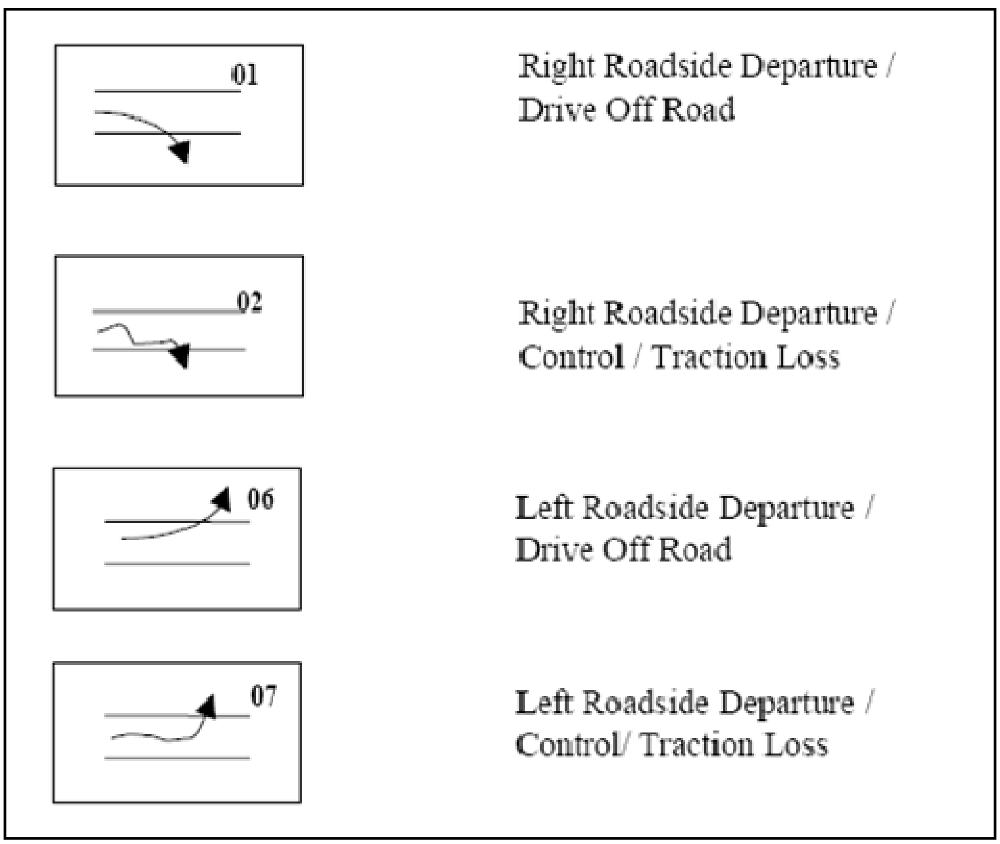

Figure 3. Single-Vehicle Roadway Departures Addressed by LDWS

- **Same-direction lane departures (SDLD):** Crashes in which a truck departed its lane of travel over the lane line and entered into a lane of traffic traveling in the *same direction as the truck* without the intention of changing lanes. LDWS can help to prevent SDLD crashes of the types shown in Figure 4, which typically result in sideswipes (NHTSA 2005, 89).

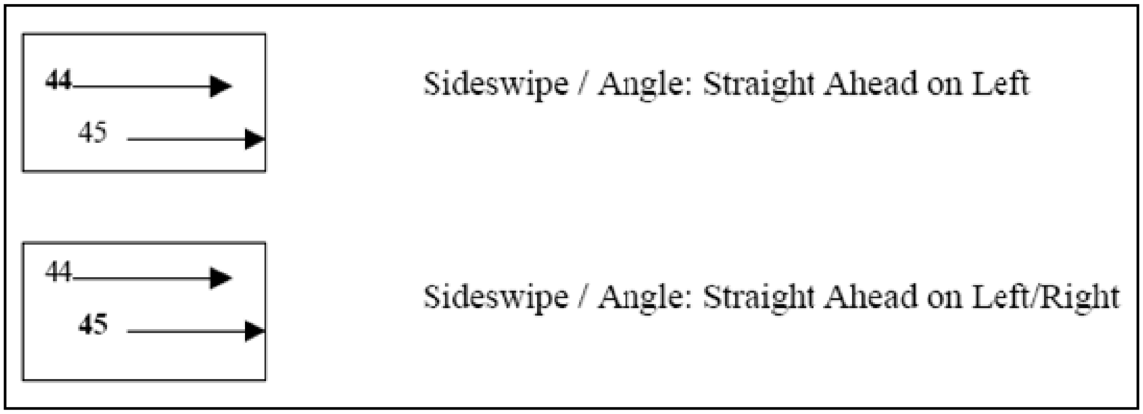

Figure 4. Same-Direction Lane Departures Addressed by LDWS

- **Opposite-direction lane departures (ODLD):** Crashes in which a truck departed its lane of travel and entered into an *oncoming-traffic* lane. LDWS can help to prevent ODLD crashes of the types shown in Figure 5**,** which typically result in sideswipes and head-on crashes (NHTSA 2005, 89).

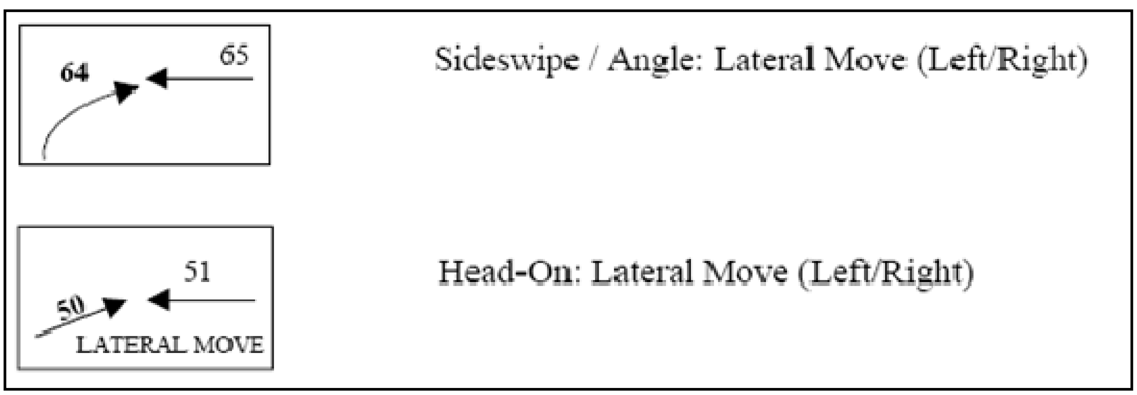

Figure 5. Opposite-Direction Lane Departures Addressed by LDWS

GES data were used as the basis for estimating costs for lane departure collisions involving PDO, injuries, injuries, and/or fatalities.

Table 1 provides the crash data for the different lane departure crash degrees of severity addressed by the LDWS. 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 B**. Since GES is a probability-based nationally representative sample of all police-reported fatal, injury, and PDO crashes, the data from GES yield national estimates, calculated using a weighting procedure. 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 lane departure crashes for large trucks that resulting in fatalities, injuries, or PDO. Next, the weighted-numbers crashes in each category were summed and divided by 5 (five years) to provide a mean annual number of crashes by crash severity.

Table 1. Mean Annual Number of Large-Truck Lane Departure Crashes by Crash Severity, 2001–2005

Crash Type	PDO Crashes	Injury Crashes	Fatal Crashes	TOTAL
SVRD	4,748	2,412	102	7,262
SDLD	4,268	563	2	4,833
ODLD	3,835	651	100	4,586
Total	**12,851**	**3,626**	**204**	**16,681**

Table 2. Mean Annual Number of Large-Truck Lane Departure Crashes by Crash Outcome and Severity, 2001–2005

Crash Outcome	PDO Crashes	Injury Crashes	Fatal Crashes	TOTAL
SVRD Collisions	3,602	982	64	4,648
SVRD Rollovers	1,146	1,430	38	2,614
SDLD Sideswipes	4,268	562	2	4,832
ODLD Sideswipes	3,737	557	37	4,331
ODLD Head-ons	98	95	63	256
Total	**12,851**	**3,626**	**204**	**16,681**

3.1.2 Efficacy of LDWS

While the crashes presented in Table 1 and Table 2 represent the average numbers of the types of crashes potentially preventable by LDWS, this technology will probably not prevent all of these crashes. For example, LDWS will not prevent crashes due to loss of steering control (brake lock-up) as a vehicle departs a lane or runs off the road, a circumstance which may have been included in this data set. Furthermore, crashes initiated by major vehicle mechanical failures, such as faulty brakes, steering loss, or tire blowouts, would not be considered preventable by LDWS systems. In addition, these systems would have limited effectiveness in a crash that occurred as a truck drifted off the roadway or struck another vehicle in an adjacent lane when the driver was incapacitated, seriously ill, or unconscious. Since these types of incidents may have occurred in the GES data sets of crashes shown in Table 2, efficacy rates were estimated for the LDWS.

Efficacy rates or crash prevention rates are the percentages of crashes that, with a high degree of probability, LDWS would prevent. Using information from the Mack FOT and motor carrier feedback, a range of efficacy rates was determined and used to estimate the percentage of these types of crashes that could be prevented by LDWS. Motor carriers provided the average number of events that occurred annually in the five-year period under study and estimated the number of crashes that could have been prevented by the use of LDWS in their operations. These efficacy rates were calculated by dividing the number of crashes preventable with the technology by the sum of the number of crashes experienced and the number of crashes avoided. As shown in Table 3, the higher rates of efficacy were determined to be 53 percent for SVRD collision (47 out of 89 collisions), 50 percent for SVRD rollovers (50 out of 101 rollovers), and 46 percent for SDLD and ODLD over-the-lane-line collisions (52 out of 113 collisions). As a result, the assumed lower rates of efficacy of LDWS in preventing the different crash outcomes came from the Mack FOT, while the higher rates were obtained from motor carrier information. Multiplying the numbers of crashes in Table 2 by these efficacy rates resulted in the estimated numbers of crashes preventable by LDWS shown in Table 3.

Table 3. Estimated Mean Annual Number of Crashes Preventable by LDWS by Crash Severity, 2001–2005

Crash Type at % Efficacy	PDO	Injury	Fatal	Total
SVRD Collisions—23% Efficacy	828	226	15	1,069
SVRD Collisions—53% Efficacy	1,909	520	34	2,463
SVRD Rollovers—24% Efficacy	275	343	9	627
SVRD Rollovers—50% Efficacy	573	715	19	1,307
SDLD Sideswipes—23% Efficacy	982	129	0	1,111
SDLD Sideswipes—46% Efficacy	1,963	259	1	2,223
ODLD Sideswipes—23% Efficacy	860	128	9	997
ODLD Sideswipes—46% Efficacy	1,719	256	17	1,992
ODLD Head-ons—23% Efficacy	23	22	14	59
ODLD Head-ons—46% Efficacy	45	44	29	118

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

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

3.2.1 Cost Data Collection Process

To develop a comprehensive estimate of crash costs, the American Transportation Research Institute (ATRI) collected cost estimates from representative motor carrier constituents within the trucking industry. As shown in **Appendix C**, the Carrier Interview Guide, carriers and insurers were asked to estimate their costs with respect to the following data collection cost categories:

- 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
- Environmental costs

- Property damage costs
- Legal costs, including attorney fees and injury and fatality settlement costs

The survey respondents described how the costs associated with these categories vary depending on the type of crash, of the major types of crashes preventable by LDWS. Baseline data were also received on the quantity and severity of crashes, categorized by type, which had occurred during the last year, as well as the number of drivers who had been injured and/or replaced. In addition, the Interview Guide included questions on costs by type of vehicle, cargo, and insurance, such as 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 C, a broad range of motor carrier fleet sizes, operational types, 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 initial interview results were synthesized, follow-up interviews were conducted with additional representatives of motor carriers, insurers, and legal firms, in order to validate responses and address any gaps in the data. They were asked about the cost factors related to areas in the data collection cost categories with respect to run-off-the road collisions, rollovers, and sideswipes, although several cost categories associated with these specific crashes do not vary by crash type.

After the 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. 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 used instead. The interview respondents were also asked how the potential crash costs presented might be affected by the severity of the crash—for example, 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 allocated as marginal costs of crashes. However, if a driver must 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 involved when a new driver is brought into the organization. Training costs included any ancillary tuition, instructor costs, and team-driver costs. Testing costs included 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 4 presents a breakout of these median costs per each new driver hired—costs provided by the interviewed motor carriers and insurance companies.

Table 4. Median Driver-Replacement Cost Categories Per Fatal or Injury Crash

Cost Category	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 their dependents against hardships from injury or death arising out of the work environment. These employees or their survivors are provided with fixed monetary awards covered under Workers' Compensation, thus eliminating the need for excessive litigation.

Employers with a certain number of employees 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.

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—covers the costs of hospitals, doctors, medical treatment, etc.
- Disability Pay—compensates for lost pay either temporarily, while the employee is recovering, or permanently, if the employee is unable to return to work. The amount paid varies, but can be as high as one-half to two-thirds of employee's pre-disability pay.
- Vocational Rehabilitation—covers costs involved in cases in which the injury renders the employee unable to perform the usual duties of his or her occupation, including re-training to enter a new trade or business and physical therapy.

The median Workers' Compensation claims of $62,728 for motor vehicle crashes were determined from insurance company data. According to insurance companies, approximately 10 percent of the Workers' Compensation costs are borne by motor carriers if they are not self-insured, and the remainder is covered by insurance, as required. In order to isolate those costs that are specific to a motor carrier, the research assumption used in this analysis is 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 account accurately for the actual labor costs associated with truck crashes, as well as the cost savings that can be expected from the use of LDWS, the researchers multiplied labor costs by the average number of injuries and fatalities incurred by truck drivers on a per-crash basis. As shown in Table 5, on average, a larger percentage of truck drivers are injured or killed per SVRD collision or rollover (90 to 100 percent) than per sideswipe and head-on (0 to 30 percent).

Table 5. Average Annual Numbers of Truck Driver Injuries and Fatalities per Crash, 2001–2005

Crash Type	Number of Injury Crashes	Number of Injuries in Crashes	Number of Injuries per Crash	Number of Fatal Crashes	Number of Fatalities in Crashes	Number of Fatalities per Crash
SVRD Collisions	982	914	0.9	64	60	0.9
SVRD Rollovers	1,430	1,398	1.0	38	38	1.0
SDLD Sideswipes	562	98	0.2	2	0	0.0
ODLD Sideswipes	557	118	0.2	37	1	0.0
ODLD Head-ons	95	14	0.1	63	21	0.3

Using these rates, the labor and Workers' Compensation costs associated with injuries and fatalities per crash have been calculated as shown in Table 6 through Table 9.

Table 6. Average Labor and Workers' Compensation Costs per SVRD Collision Crash

Cost Category	Injury Crash	Fatal Crash
Driver Replacement	$6,300	$6,300
Workers' Compensation	$56,455	$56,455
Total	**$62,755**	**$62,755**

Table 7. Average Labor and Workers' Compensation Costs per SVRD Rollover Crash

Cost Category	Injury Crash	Fatal Crash
Driver Replacement	$7,000	$7,000
Workers' Compensation	$62,728	$62,728
Total	**$69,728**	**$69,728**

Table 8. Average Labor and Workers' Compensation Costs per ODLD and SDLD Sideswipe Crash

Cost Category	Injury Crash	Fatal Crash
Driver Replacement	$1,400	$0
Workers' Compensation	$12,546	$0
Total	**$13,946**	**$0**

Table 9. Average Labor and Workers' Compensation Costs per ODLD Head-on Crash

Cost Category	Injury Crash	Fatal Crash
Driver Replacement	$700	$2,100
Workers' Compensation	$6,273	$18,818
Total	**$6,973**	**$20,918**

3.2.4 Operational Costs

Operational costs considered in this analysis included direct costs associated with cargo damage, delivery delays, and loading and unloading, 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 SVRD collision, head-on, rollover, or sideswipe crash are presented in Table 10. Cargo damage costs, which can reflect extreme ranges in cargo value, included the direct average damage to the cargo that occurred as a result of the crash. Cargo delivery delay costs included any penalties or reimbursements that the carrier pays 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 the truck (including both the tractor and trailer) being towed from the crash site. In addition, there were the inventory and cargo storage costs. Miscellaneous costs included a summation of smaller crash-related costs, such as the additional expenses associated with calling the customer after the crash, and any crash-associated public relations costs. Additional motor carrier operational costs that could be associated with crashes, such as costs for emergency supplies (cones, flares, etc.), were described by the interviewed carriers as typical "costs of doing business"; therefore, they were not included in this analysis.

As shown in Table 10, overall operational costs were estimated to be approximately $28,900 for SVRD collisions, $28,625 for SVRD rollover crashes, and $13,650 for sideswipes and head-on crashes, but these total costs could vary considerably, depending primarily on the value of the damaged cargo.

Table 10. Median Operational Costs per Crash

Cost Category	SVRD Collisions	SVRD Rollovers	SDLD and ODLD Sideswipes	ODLD Head-ons
Cargo damage	$17,500	$15,000	$5,000	$5,000
Cargo delivery delays	$800	$2,875	$750	$750
Loading and unloading cargo	$2,000	$1,850	$2,500	$2,500
Towing, inventory, and storage	$8,250	$8,500	$5,000	$5,000
Miscellaneous	$400	$400	$400	$400
Total	**$28,950**	**$28,625**	**$13,650**	**$13,650**

Additional operational costs considered for inclusion in this analysis were citations and penalties resulting from crashes. Lane departure crashes may involve fines for such citations as speeding or 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 environmental remediation companies, environmental clean-up costs tended to vary depending on whether or not a body of water was impacted and required clean-up. Based on average invoices, the costs for water-impacted clean-up ranged from $500 to over $100,000 per crash, depending on the type of waterway involved. If a body of water was not , the clean-up costs ranged from $300 to over $20,000 per crash. The variability in range of cost in both cases—water impacted and no water impacted—depended on what type of substance was leaked or spilled, and the amount involved.

In addition to these costs, a carrier may be required to pay fines for the environmental damage caused. The costs of these fines also varied based on the severity of the crash and on whether or not water was impacted. Carriers reported that the average environmental fine for a crash in which no water was impacted is $4,000; the average environmental fine for a crash in which water was impacted was $7,500. For this analysis, the conservative figure of $4,000 is used as the environmental fine per crash. The total median environmental costs used in this analysis are shown in Table 11.

Table 11. Median Environmental Costs per Crash

Cost Category	SVRD Collisions	SVRD Rollovers	SDLD and ODLD Sideswipes	ODLD Head-ons
Environmental fine (no water impacted)	$4,000	$4,000	$4,000	$4,000
Out-of-pocket environmental clean-up costs	$31,000	$78,500	$20,000	$20,000
Total	**$35,000**	**$82,500**	**$24,000**	**$24,000**

3.2.6 Property Damage Costs

Median costs for property damage in crashes, as provided by the interviewed insurers and carriers for crashes addressed by LDWS, are presented in Table 12**.** Infrastructure and surrounding structural damage refer to the crash-caused damage to structures other than the truck, such as any damage 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.

Table 12. Median Property Damage Costs per Crash

Cost Category	SVRD Collisions	SVRD Rollovers	SDLD and ODLD Sideswipes	ODLD Head-ons
Damage to structures other than the truck	$2,500	$2,500	$2,500	$2,500
PDO to truck	$31,667	$53,333	$25,000	$25,000
Total	**$34,167**	**$55,833**	**$27,500**	**$27,500**

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 typically vary considerably, depending on negligence, and on the type and severity of the crash.

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 13 through Table 16 for each type of crash addressed by LDWS.

Table 13. Average Legal Fees and Court Costs per SVRD Collision Crash

Cost Category	PDO Crash	Injury Crash	Fatal Crash
Legal Fees	$20,000	$40,000	$150,000
Court Costs	$20,000	$20,000	$20,000
Total	**$40,000**	**$60,000**	**$170,000**

Table 14. Average Legal Fees and Court Costs per SVRD Rollover Crash

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

Table 15. Average Legal Fees and Court Costs per ODLD and SDLD Sideswipe Crash

Cost Category	PDO Crash	Injury Crash	Fatal Crash
Legal Fees	$15,000	$25,000	$100,000
Court Costs	$20,000	$20,000	$20,000
Total	**$35,000**	**$45,000**	**$120,000**

Table 16. Average Legal Fees and Court Costs per Head-on Crash

Cost Category	PDO Crash	Injury Crash	Fatal Crash
Legal Fees	$20,000	$25,000	$100,000
Court Costs	$20,000	$20,000	$20,000
Total	**$40,000**	**$45,000**	**$120,000**

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 is $10,000 for sideswipe crashes, $167,500 for rollovers, $120,000 for roadway departure crashes, and $93,000 for head-on crashes.

For this analysis, the costs per injury or fatality depended on the average number of injuries and fatalities in crashes preventable by the LDWS. GES data provided the numbers of injuries and fatalities in the crashes preventable by the LDWS, which were used to calculate the average number of injuries in injury crashes and the average number of injuries and fatalities in a fatal crash. Table 17 presents these results. A detailed summary of the numbers of injuries and fatalities per year in these crashes is provided in **Appendix A**.

Table 17. Average Annual Numbers of Injuries and Fatalities per 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 SVRD Collisions	982	1,087	1.1	N/A	N/A
Injury SVRD Rollovers	1,430	1,630	1.1	N/A	N/A
Injury SDLD Sideswipes	562	640	1.1	N/A	N/A
Injury ODLD Sideswipes	557	761	1.4	N/A	N/A
Injury ODLD Head-ons	95	132	1.4	N/A	N/A
Fatal SVRD Collisions	64	8	0.1	81	1.3
Fatal SVRD Rollovers	38	0	0.0	38	1.0
Fatal SDLD Sideswipes	2	0	0.0	2	1.0
Fatal ODLD Sideswipes	37	40	1.1	38	1.0
Fatal ODLD Head-ons	63	103	1.6	63	1.0

Table 18 through Table 22 show the average cost per injury crash and per fatality crash involving a crash preventable by the LDWS. These results were obtained by multiplying the annual average numbers of fatalities and/or injuries per crash type in Table 17 by the respective settlement costs for one fatality and one injury for sideswipes, rollovers, roadway departures, and head-ons.

Table 18. Average Settlement Costs per Injury and Fatal SVRD Collision Crash

Cost Category	Injury Crash	Fatal Crash
Out-of-Pocket Costs per Injury	$132,000	$12,000
Out-of-Pocket per Fatality	N/A	$910,000
Total	**$132,000**	**$922,000**

Table 19. Average Settlement Costs per Injury and Fatal SVRD Rollover Crash

Cost Category	Injury Crash	Fatal Crash
Out-of-Pocket Costs Per Injury	$184,250	$0
Out-of-Pocket per Fatality	N/A	$700,000
Total	**$184,250**	**$700,000**

Table 20. Average Settlement Costs per Injury and Fatal SDLD Sideswipe Crash

Cost Category	Injury Crash	Fatal Crash
Out-of-Pocket Costs Per Injury	$11,000	$0
Out-of-Pocket per Fatality	N/A	$700,000
Total	**$11,000**	**$700,000**

Table 21. Average Settlement Costs per Injury and Fatal ODLD Sideswipe Crash

Cost Category	Injury Crash	Fatal Crash
Out-of-Pocket Costs Per Injury	$14,000	$11,000
Out-of-Pocket per Fatality	N/A	$700,000
Total	**$14,000**	**$711,000**

Table 22. Average Settlement Costs per Injury and Fatal Head-on Crash

Cost Category	Injury Crash	Fatal Crash
Out-of-Pocket Costs Per Injury	$130,200	$148,800
Out-of-Pocket per Fatality	N/A	$700,000
Total	**$130,200**	**$848,800**

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

Based on the average cost estimates from the previous subsections, Table 23 summarizes the major crash costs, which could have been avoided through the use of LDWS. These costs are based on a typical or average incident; therefore, they should be interpreted as approximations of typical expected values.

Table 23. Cost Estimates per Crash by Crash Type and Crash Severity for Lane Departure Crashes

Crash Type and Severity	Labor and Workers' Comp.	Operational	Environ-mental	Property Damage	Legal Settlement	Court Costs and Other Legal Fees	Total
PDO SVRD Collisions	N/A	$28,950	$35,000	$34,167	N/A	$40,000	**$138,117**
Injury SVRD Collisions	$62,755	$28,950	$35,000	$34,167	$132,000	$60,000	**$352,872**
Fatal SVRD Collisions	$62,755	$28,950	$35,000	$34,167	$922,000	$170,000	**$1,252,872**
PDO SVRD Rollovers	N/A	$28,625	$82,500	$55,833	N/A	$30,000	**$196,958**
Injury SVRD Rollovers	$69,728	$28,625	$82,500	$55,833	$184,250	$35,000	**$455,936**
Fatal SVRD Rollovers	$69,728	$28,625	$82,500	$55,833	$700,000	$110,000	**$1,046,686**
PDO SVRD Head-ons	N/A	$13,650	$24,000	$27,500	N/A	$40,000	**$105,150**
Injury SVRD Head-ons	$6,973	$13,650	$24,000	$27,500	$130,200	$45,000	**$247,323**
Fatal SVRD Head-ons	$20,918	$13,650	$24,000	$27,500	$848,800	$120,000	**$1,054,868**
PDO SDLD Sideswipes	N/A	$13,650	$24,000	$27,500	N/A	$35,000	**$100,150**
Injury SDLD Sideswipes	$13,946	$13,650	$24,000	$27,500	$11,000	$45,000	**$135,096**
Fatal SDLD Sideswipes	$0	$13,650	$24,000	$27,500	$700,000	$120,000	**$885,150**
PDO ODLD Sideswipes	N/A	$13,650	$24,000	$27,500	N/A	$35,000	**$100,150**
Injury ODLD Sideswipes	$13,946	$13,650	$24,000	$27,500	$14,000	$45,000	**$138,096**
Fatal ODLD Sideswipes	$0	$13,650	$24,000	$27,500	$711,000	$120,000	**$896,150**

This analysis is based on the assumption that these crash costs would be incurred by motor carriers which have deductibles at the total crash cost level or are self-insured. By Code of Federal Regulations requirements (49 CFR 387), 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 motor carrier's ability to satisfy its obligation for coverage of bodily injury liability, property damage liability, and/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 23.

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 deductibles 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 premium rates.

Due to the high cost of truck crashes, major truck insurance providers and various truck fleets indicated that paying premiums is a significant business expense that most fleets would like to reduce. However, it should be noted that it is difficult to attribute a standardized premium increase directly 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 in premiums of approximately 8 to 15 percent annually—independent of crash history.

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

While Step 1 provides information on the numbers of truck crashes preventable by LDWS, and Step 2 provides estimates of the costs of those crashes, motor carriers ultimately need to know the crash cost savings that they can expect from the use of the LDWS. As a result, Step 3 involves estimating crash avoidance costs based on vehicle miles traveled and expected crash reduction from deploying LDWS.

The average annual truck VMT can vary dramatically depending on the motor carrier's operations. As the average VMT per truck increases, the likelihood of a truck being involved in a crash will increase as well, due to increased exposure. To take into account the variances in the average VMTs 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.

To determine the costs of crashes preventable by LDWS for the various annual VMT values shown in Table 24 and Table 25, the first step was to divide the estimated mean annual number of crashes preventable by LDWS from Tables 2 and 3 by the mean annual total number of vehicle miles traveled (VMT) of large trucks in the United States of 217,488 million miles, as reported in Table VM-1 of the Federal Highway Statistics Publications from 2001 to 2005 (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 Tables 24 and 25 provide an estimate of the crash costs that can be avoided through the use of LDWS at the low and high efficacy rates and VMTs. The resulting expected total costs are the sum of the probability of each possible outcome of the crashes preventable by LDWS multiplied by its estimated cost. Each total cost value represents the average annual amount one "expects" as the cost of the crash per vehicle at a different average VMT, with identical odds repeated many times for each VMT category.

Table 24. LDWS: Average Annual Crash Costs per Crash Avoided for an Average Annual VMT at Low Efficacy Rates

Crash Type and Severity	80,000 VMT	100,000 VMT	120,000 VMT	140,000 VMT	160,000 VMT
PDO SVRD Collisions	$42	$53	$63	$74	$84
Injury SVRD Collisions	$29	$37	$44	$51	$59
Fatal SVRD Collisions	$7	$9	$10	$12	$14
PDO SVRD Rollovers	$20	$25	$30	$35	$40
Injury SVRD Rollovers	$58	$72	$86	$101	$115
Fatal SVRD Rollovers	$3	$4	$5	$6	$7
PDO SDLD Sideswipes	$36	$45	$54	$63	$72
Injury SDLD Sideswipes	$6	$8	$10	$11	$13
Fatal SDLD Sideswipes	$0	$0	$0	$0	$0
PDO ODLD Sideswipes	$32	$40	$48	$55	$63
Injury ODLD Sideswipes	$7	$8	$10	$11	$13
Fatal ODLD Sideswipes	$3	$4	$4	$5	$6
PDO SVRD Head-ons	$1	$1	$1	$2	$2
Injury SVRD Head-ons	$2	$3	$3	$4	$4
Fatal SVRD Head-ons	$5	$7	$8	$10	$11
Total Cost	**$251**	**$314**	**$377**	**$440**	**$503**

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

Table 25. LDWS: Average Annual Crash Costs per Crash Avoided for an Average Annual VMT at High Efficacy Rates

Crash Type and Severity	80,000 VMT	100,000 VMT	120,000 VMT	140,000 VMT	160,000 VMT
PDO SVRD Collisions	$97	$121	$145	$170	$194
Injury SVRD Collisions	$67	$84	$101	$118	$135
Fatal SVRD Collisions	$16	$20	$24	$27	$31
PDO SVRD Rollovers	$42	$52	$62	$73	$83
Injury SVRD Rollovers	$120	$150	$180	$210	$240
Fatal SVRD Rollovers	$7	$9	$11	$13	$15
PDO SDLD Sideswipes	$72	$90	$108	$127	$145
Injury SDLD Sideswipes	$13	$16	$19	$23	$26
Fatal SDLD Sideswipes	$0	$0	$0	$1	$1
PDO ODLD Sideswipes	$63	$79	$95	$111	$127
Injury ODLD Sideswipes	$13	$16	$20	$23	$26
Fatal ODLD Sideswipes	$6	$7	$8	$10	$11
PDO SVRD Head-ons	$2	$2	$3	$3	$3
Injury SVRD Head-ons	$4	$5	$6	$7	$8
Fatal SVRD Head-ons	$11	$14	$17	$20	$23
Total Cost	**$533**	**$667**	**$800**	**$933**	**$1,067**

*****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 the fourth step in the benefit-cost analysis to determine the costs of purchasing and deploying LDWS. The technology and deployment cost estimates for LDWS include the technology purchasing price, as well as the costs for installation, maintenance, and training drivers in the use of the technology. These costs considered purchases of the technology both with and without financing.

4.1 STEP 4: ESTIMATE THE TECHNOLOGY AND DEPLOYMENT COSTS

Deployment costs include the cost of purchasing and installing LDWS. Based on input from LDWS suppliers and truck fleets that have acquired LDWS, current deployment costs vary based on the number of units purchased. According to one LDWS supplier, per-unit prices for “moderate volume” purchases are about $1,000. The Mack FOT evaluation report included estimates of less than $1,000 for large-volume purchases and from $1,000 to $1,500 for purchase and installation of a single aftermarket LDWS—estimates which coincided with information from carriers that have purchased these systems. For retrofitted LDWS, the approximate installation time is less than 90 minutes. Suppliers contacted for this study indicated little difference in cost between an aftermarket purchase of LDWS and an OEM-specified LDWS. The estimated cost of the LDWS for this analysis was estimated to be approximately $1,000.

These costs are based on the assumption that the motor carrier has the cash 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 26**.** 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 loan period of three years.

Table 26. Cost of LDWS, if Financed

Book Price	Year 1	Year 2	Year 3	Total
$1,000	$367.13	$367.13	$367.13	$1,101.39

It is noteworthy that motor carriers derive Federal tax savings from the depreciation of the 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[†]). LDWSs installed by the OEM are considered 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 27 (Internal Revenue 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

[*] 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 particular profits.

LDWS. 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 27. Federal Tax Savings due to Depreciation of LDWS

Year 1	Year 2	Year 3	Year 4	Year 5
-$116.66	-$155.58	-$51.84	-$25.94	$0.00

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 the amount of time typically spent training a driver. The costs of trainers, manuals, and other training materials were excluded, since they may be part of a carrier's typical training budget, or may be provided by the system vendors.

Motor carriers reported in interviews that maintenance was minimal and did not incur significant costs unless a windshield was damaged and the LDWS camera needed to be reinstalled on the new windshield. As a result of these findings, maintenance costs were determined to be negligible. As shown in Table 28, the total costs of the technology, plus the added training costs and minus the Federal tax savings, are provided for both the financed and non-financed purchase options.

Table 28. Total Costs of Technology Deployment with and without Financing

Technology	Year 1	Year 2	Year 3	Year 4	Year 5	Total*
LDWS	$906.35	-$132.58	-$28.84	-$2.94	$23.00	$765.00
LDWS (financed)	$273.48	$234.56	$338.30	-$2.94	$23.00	$866.40

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

5. BENEFIT-COST ANALYSIS CALCULATIONS

This section presents an overview of the benefit-cost analysis calculations. Specifically, the benefits in terms of crash cost avoidance were compared to the costs in terms of total technology costs.

5.1 STEP 5: CALCULATE NET PRESENT VALUES OF BENEFITS AND COSTS

The present values of the LDWS were computed by discounting future benefits and costs for the values in Steps 3 and 4, using discount rates of 3 and 7 percent over a five-year period (Office of Management and Budget 1992). Discounting benefits and costs transforms gains and losses occurring in different time periods to a common unit of measurement. Economic conditions and externalities dictate which rate is most appropriate for calculating benefits. The higher the discount rate, the lower the present value of future cash flows. For typical investments, with costs concentrated in early periods and benefits following in later periods, raising the discount rate tends to reduce the net present value. The discounted benefits of the LDWS are shown in Table 29 and

Table 30 at the low and high efficacy rates. The discounted cost of the LDWS is shown in Table 31.

Table 29. Present Value of the Benefits of LDWS at Low Efficacy Rates Using 3% and 7% Discount Rates

Average VMT		
80,000	$1,150.82	$1,030.32
100,000	$1,438.52	$1,287.90
120,000	$1,726.22	$1,545.48
140,000	$2,013.93	$1,803.06
160,000	$2,301.63	$2,060.64

Table 30. Present Value of the Benefits of LDWS at High Efficacy Rates Using 3% and 7% Discount Rates

Average VMT	3%	7%
80,000	$2,442.50	$2,186.76
100,000	$3,053.13	$2,733.45
120,000	$3,663.75	$3,280.14
140,000	$4,274.38	$3,826.84
160,000	$4,885.00	$4,373.53

Table 31. Present Value of the Costs of LDWS Using 3% and 7% Discount Rates

No Financing and 3%	No Financing and 7%	Financing and 3%	Financing and 7%
$745.83	$721.88	$813.43	$750.77

When the anticipated costs and benefits of the LDWS are compared, the benefits of using the system over a period of five years outweigh the costs associated with purchasing the systems at each efficacy rate and for each VMT category. For every dollar spent, carriers received more than a dollar back in benefits that could be quantified for this analysis. To demonstrate this effect, Table 32 and Table 33 present the average benefits a motor carrier could expect to receive for each dollar invested in LDWS.

Table 32. Anticipated Benefits per Dollar Spent for Purchasing LDWS, without Financing

Average VMT	3% Discount Rate—Low Efficacy	3% Discount Rate—High Efficacy	7% Discount Rate—Low Efficacy	7% Discount Rate—High Efficacy
80,000	$1.54	$3.27	$1.43	$3.03
100,000	$1.93	$4.09	$1.78	$3.79
120,000	$2.31	$4.91	$2.14	$4.54
140,000	$2.70	$5.73	$2.50	$5.30
160,000	$3.09	$6.55	$2.85	$6.06

Table 33. Anticipated Benefits per Dollar Spent for Purchasing LDWS, with Financing

Average VMT	3% Discount Rate—Low Efficacy	3% Discount Rate—High Efficacy	7% Discount Rate—Low Efficacy	7% Discount Rate—High Efficacy
80,000	$1.41	$3.00	$1.37	$2.91
100,000	$1.77	$3.75	$1.72	$3.64
120,000	$2.12	$4.50	$2.06	$4.37
140,000	$2.48	$5.25	$2.40	$5.10
160,000	$2.83	$6.01	$2.74	$5.83

5.1.1 Payback Periods

Payback periods were calculated to determine the length of time required to recover the initial investments made for the LDWS. Although the motor carrier can expect to reap a return on investment by purchasing the technology, the amount of time it will take for the motor carrier to realize the positive benefits after purchasing the system varies according to the average VMT per truck and the type of the technology. Shorter payback periods reflect less funding risk. The payback period does not address the time value of money, nor does it go beyond the initial recovery of the investment. The formula is:

$$\frac{SystemCost}{AnnualCashInflow} = PaybackPeriod$$

For example, with the cost of $765 for the LDWS and the expected to return of $533 annually for a VMT of 80,000 at the high efficacy rate, the payback period would be $765 divided by $533, which equals 1.43 years or about 17 months.

The payback periods are shown in Table 34. In all cases, motor carriers with costs similar to those assumed for this analysis can expect a payback period well within the anticipated lifetime of the technology.

Table 34. Payback Period in Months

VMT	Low Efficacy	High Efficacy
80,000	37	17
100,000	29	14
120,000	24	11
140,000	21	10
160,000	18	9

5.1.2 Indirect Costs

The previous sections provide information about the direct costs of preventable crashes that could be reasonably quantified; however, decisions relating to the purchase of the LDWS should also include the consideration of indirect costs.

To gain a broader understanding of the importance of all crash costs to motor carriers, a survey questionnaire was delivered to motor carrier members of the Commercial Vehicle Safety Alliance (CVSA), the American Trucking Associations (ATA), and select affiliated state trucking associations. In all, 56 motor carriers responded to the questionnaire. The respondents represented a broad range of motor carrier fleet sizes, operational types, and characteristics. Although the distribution of respondents by demographic factors did not necessarily replicate the statistical distributions of the motor carrier industry, the respondents represented a distribution of carrier types sufficiently broad to make it an adequate sample from which to infer motor carrier perceptions.

The motor carriers were asked to rate the importance to their companies of each of 21 crash impacts presented in a list using a scale of 1 to 5, with 1 being “Not Very Significant” and 5 being “Very Significant.” Table 35 presents the ranking of crash cost importance based on the value of the responses.

These results showed that the first 12 top-ranked crash cost areas included indirect costs, such as impacts on insurance costs, public image, and employee morale, as true impacts to carriers. The fact that LDWSs have the potential to address these important indirect costs can add to the benefits of purchasing these systems.

Table 35. Motor Carrier Perceptions of Crash Cost Importance

Crash Impact	Rank Based on Mean Importance	Mean Perception of Crash Cost Importance
Impact on liability insurance rates	1	4.59
Equipment and property damage	2	4.50
Cost of replacing drivers	3	4.45
Impact on Federal safety rating	4	4.37
Crash-related legal expenses	5	4.29
Impact on Workers' Compensation rates	6	4.25
Impact on medical insurance costs	7	4.21
Loss of customer goodwill and/or business	8	4.15
Impact on public image	9	4.13
Environmental clean-up costs	10	4.06
Cargo damage/loss	11	4.04
Impact on employee morale	12	4.04
Reimbursement of emergency response costs	13	3.85
Cost of management time spent on crash settlement	14	3.74
Liability from automated data collection via technology	16	3.73
Cost of off-loading cargo and transport by relief vehicle	15	3.73
Cost of towing/recovering damaged vehicle	17	3.70
Cost of accident investigation	18	3.66
Crash-related fines	19	3.64
Crash-related administrative costs	20	3.42
Shipping penalties	21	3.12

5.2 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 may fall outside the normal scope of carrier operations and assumptions used for the crash cost estimates in Step 2. This sensitivity analysis was included to provide some context for small carriers, since this BCA overall assessment uses economic assumptions that may be more pertinent to medium-sized and large carriers. However, FMCSA and ATRI are presently undertaking a separate OSS assessment focusing on the unique issues and economics of small carriers. Finally, this Step 6 sensitivity analysis can also be applied to high-value cargo carriers.

5.2.1 Small Carriers

It is important to consider small carriers separately from large carriers because of 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. The median deductible for a motor carrier will fall near the low end of the $5,000–$50,000 range. Assuming that the probability that a small carrier will be involved in a crash is the same as in the original analysis, the estimated costs of a rollover crash with the insurance deductibles of $50,000 and $5,000 are shown in Table 36 and Table 37, respectively. Also, this cost estimate uses approximately 10 percent of the Workers' Compensation costs that may be borne by typical insured motor carriers. Other costs that were assumed to be directly covered by small carriers (that is, not covered by insurance policies) included driver replacement costs and the operational costs for cargo delivery delays; loading and unloading cargo; towing, inventory, and storage; and miscellaneous costs. Environmental costs were also assumed to be carrier out-of-pocket costs not covered by insurance.

Table 36. Cost Estimates per Crash by Crash Type and Crash Severity for Lane Departure Crashes with Insurance Deductible of $50,000

Crash Type and Severity	Driver Replace-ment	Workers' Comp.	Operational: Cargo and Delivery Delays	Operational: Loading and Unloading Cargo	Operational: Towing, Inventory, and Storage	Operational: Misc.	Environ-mental	Insurance Deductible	Total
PDO SVRD Collisions	N/A	N/A	$800	$2,000	$8,250	$400	$35,000	$50,000	**$96,450**
Injury SVRD Collisions	$6,300	$5,645	$800	$2,000	$8,250	$400	$35,000	$50,000	**$108,395**
Fatal SVRD Collisions	$6,300	$5,645	$800	$2,000	$8,250	$400	$35,000	$50,000	**$108,395**
PDO SVRD Rollovers	N/A	N/A	$2,875	$1,850	$8,500	$400	$82,500	$50,000	**$146,125**
Injury SVRD Rollovers	$7,000	$6,273	$2,875	$1,850	$8,500	$400	$82,500	$50,000	**$159,398**
Fatal SVRD Rollovers	$7,000	$6,273	$2,875	$1,850	$8,500	$400	$82,500	$50,000	**$159,398**
PDO SVRD Head-ons	N/A	N/A	$750	$2,500	$5,000	$400	$24,000	$50,000	**$82,650**
Injury SVRD Head-ons	$700	$627	$750	$2,500	$5,000	$400	$24,000	$50,000	**$83,997**
Fatal SVRD Head-ons	$2,100	$1,820	$750	$2,500	$5,000	$400	$24,000	$50,000	**$86,570**
PDO SDLD Sideswipes	N/A	N/A	$750	$2,500	$5,000	$400	$24,000	$50,000	**$82,650**
Injury SDLD Sideswipes	$1,400	$1,255	$750	$2,500	$5,000	$400	$24,000	$50,000	**$85,305**
Fatal SDLD Sideswipes	$0	$0	$750	$2,500	$5,000	$400	$24,000	$50,000	**$82,650**
PDO ODLD Sideswipes	N/A	N/A	$750	$2,500	$5,000	$400	$24,000	$50,000	**$82,650**
Injury ODLD Sideswipes	$1,400	$1,255	$750	$2,500	$5,000	$400	$24,000	$50,000	**$85,305**
Fatal ODLD Sideswipes	$0	$0	$750	$2,500	$5,000	$400	$24,000	$50,000	**$82,650**

Table 37. Cost Estimates per Crash by Crash Type and Crash Severity for Lane Departure Crashes with Insurance Deductible of $5,000

Crash Type and Severity	Driver Replace-ment	Workers' Comp.	Operational: Cargo and Delivery Delays	Operational: Loading and Unloading Cargo	Operational: Towing, Inventory, and Storage	Operational: Misc.	Environ-mental	Insurance Deductible	Total
PDO SVRD Collisions	N/A	N/A	$800	$2,000	$8,250	$400	$35,000	$5,000	**$51,450**
Injury SVRD Collisions	$6,300	$5,645	$800	$2,000	$8,250	$400	$35,000	$5,000	**$63,395**
Fatal SVRD Collisions	$6,300	$5,645	$800	$2,000	$8,250	$400	$35,000	$5,000	**$63,395**
PDO SVRD Rollovers	N/A	N/A	$2,875	$1,850	$8,500	$400	$82,500	$5,000	**$101,125**
Injury SVRD Rollovers	$7,000	$6,273	$2,875	$1,850	$8,500	$400	$82,500	$5,000	**$114,398**
Fatal SVRD Rollovers	$7,000	$6,273	$2,875	$1,850	$8,500	$400	$82,500	$5,000	**$114,398**
PDO SVRD Head-ons	N/A	N/A	$750	$2,500	$5,000	$400	$24,000	$5,000	**$37,650**
Injury SVRD Head-ons	$700	$627	$750	$2,500	$5,000	$400	$24,000	$5,000	**$38,997**
Fatal SVRD Head-ons	$2,100	$1,820	$750	$2,500	$5,000	$400	$24,000	$5,000	**$41,570**
PDO SDLD Sideswipes	N/A	N/A	$750	$2,500	$5,000	$400	$24,000	$5,000	**$37,650**
Injury SDLD Sideswipes	$1,400	$1,255	$750	$2,500	$5,000	$400	$24,000	$5,000	**$40,305**
Fatal SDLD Sideswipes	$0	$0	$750	$2,500	$5,000	$400	$24,000	$5,000	**$37,650**
PDO ODLD Sideswipes	N/A	N/A	$750	$2,500	$5,000	$400	$24,000	$5,000	**$37,650**
Injury ODLD Sideswipes	$1,400	$1,255	$750	$2,500	$5,000	$400	$24,000	$5,000	**$40,305**
Fatal ODLD Sideswipes	$0	$0	$750	$2,500	$5,000	$400	$24,000	$5,000	**$37,650**

The total values in Table 38 and Table 39 provide an estimate of the expected value of crash costs that can be avoided through the use of LDWS at different efficacy rates and at a typical VMT of 100,000. The resulting expected total costs are the sum of the probability of each possible outcome of the crashes preventable by LDWS multiplied by its estimated cost.

Table 38. LDWS: Average Annual Crash Costs per Crash Avoided for an Average Annual VMT of 100,000 VMT at Low Efficacy Rates

Deductible	PDO	Injury	Fatal	Total Cost*
$5,000	$65	$30	$1	$96
$50,000	$126	$47	$2	$176

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

Table 39. LDWS: Average Annual Crash Costs per Crash Avoided for an Average Annual VMT of 100,000 VMT at High Efficacy Rates

Deductible	PDO	Injury	Fatal	Total Cost
$5,000	$136	$63	$3	$202
$50,000	$265	$100	$5	$370

After determining the net present values of the costs and benefits of LDWS, the anticipated benefits for purchasing the LDWS per dollar spent were calculated for 100,000 VMT; they are shown below in Table 40 and Table 41. It was assumed that most small carriers would finance the purchase of the technology; therefore, the present value of the financed costs of LDWS at 3 percent and 7 percent from Table 31 were used to determine the results.

Table 40. Anticipated Benefits per Dollar Spent for Purchasing LDWS per Crash Avoided for an Average Annual VMT of 100,000 VMT, 3% Discount Rate with Financing

Deductible	Low Efficacy	High Efficacy
$5,000	$0.54	$1.14
$50,000	$0.99	$2.08

Table 41. Anticipated Benefits per Dollar Spent for Purchasing LDWS per Crash Avoided for an Average Annual VMT of 100,000 VMT, 7% Discount Rate with Financing

Deductible	Low Efficacy	High Efficacy
$5,000	$0.52	$1.10
$50,000	$0.96	$2.02

Since many lane departure crashes involving large trucks may not include environmental costs, the benefits of the LDWS at 3 percent and at 7 percent could be even lower than the values shown in Tables 40 and 41 for carriers that are not self-insured. At an annual average 100,000 VMT, the benefits would range from $0.61 per dollar spent on LDWS at a low efficacy rate to

$1.32 per dollar spent on LDWS at a high efficacy rate for carriers with a $50,000 deductible, if no environmental costs are included in the analyses.

Based on the overall probability of involvement in the types of crashes preventable by LDWS, a small carrier may not reach the level of a dollar or more of benefits for each dollar spent on financing the technology over five years. However, an excessive number of crashes in a short time period can seriously affect a small carrier's insurance premiums and deductible levels. As the number of crashes increases, so will the insurance costs, until the insurance costs equal or exceed the original LDWS investment, or until, eventually, the carrier is dropped by the insurer. The formula for such a consequence varies by number of crashes, crash severity, and timeline. For this reason, an investment in the technology may still be considered prudent for added protection against rising insurance costs.

When the risk of involvement in a rollover crash is spread over the entire population of motor carriers, the benefits may not always exceed the costs for small carriers. However, benefits may still exist for small carriers. The overall probability of being involved in an unintended-lane-departure crash is low, but once it occurs, the costs to the small carrier can increase dramatically. According to insurance industry data, for a deductible level of $5,000 per crash, the annual premium payment will be approximately $4,000 per power unit. Estimates suggest that as long as the average loss per power unit does not exceed 50–65 percent of the total premium payment, the annual premium for the motor carrier may not increase. At the $4,000 premium used in this discussion, to prevent a rate increase, the average loss per power unit cannot exceed $2,618.

Insurance companies consider many factors when determining motor carrier premium payments. However, if the insurance provider is not able to generate its required return, or experiences a loss as a result of covering a particular carrier, it is highly likely that the insurance provider will increase the motor carrier's annual premiums. For example, increasing the $4,000 premium by 10 percent because of a lane departure crash results in a new annual premium per truck of $4,400, an increase of $400 per truck. Over a five-year period, without any further premium increases above the $400 per truck, this is an additional cost in premium payments of $2,000 per power unit. In contrast, the expected cost associated with financing the LDWS is $866.40. If the purchase of this unit prevents a crash that would result in higher insurance premiums, it will save a motor carrier nearly $1,133 per power unit over five years.

Nevertheless, it is recognized that small carriers do not always have the front-end liquidity or financial borrowing capacity to invest even in systems that generate a positive ROI.

5.2.2 High-Value Cargo Carriers

For high-value cargo carriers, the costs associated with the damage to high-value cargo will be greater than the average carrier's costs. For example, if the cargo damage costs range from $50,000 to $1,000,000, instead of an average of $15,000, the total estimated crash costs for SVRD rollovers increase by $35,000 and $985,000, respectively, due to operational cost changes. The total crash costs accounting for these differences are shown in Table 42 and Table 43.

Table 42. Cost Estimates per Lane Departure Crash by Crash Severity with High-Value Cargo Damages of $50,000

Crash Type and Severity	Labor and Workers' Comp.	Operational	Environ-mental	Property Damage	Legal Settlement	Court Costs and Other Legal Fees	Total
PDO SVRD Collisions	N/A	$61,450	$35,000	$34,167	$0	$40,000	**$170,617**
Injury SVRD Collisions	$62,755	$61,450	$35,000	$34,167	$132,000	$60,000	**$385,372**
Fatal SVRD Collisions	$62,755	$61,450	$35,000	$34,167	$922,000	$170,000	**$1,285,372**
PDO SVRD Rollovers	N/A	$63,625	$82,500	$55,833	$0	$30,000	**$231,958**
Injury SVRD Rollovers	$69,728	$63,625	$82,500	$55,833	$184,250	$35,000	**$490,936**
Fatal SVRD Rollovers	$69,728	$63,625	$82,500	$55,833	$700,000	$110,000	**$1,081,686**
PDO SVRD Head-ons	N/A	$58,650	$24,000	$27,500	$0	$40,000	**$150,150**
Injury SVRD Head-ons	$6,973	$58,650	$24,000	$27,500	$130,200	$45,000	**$292,323**
Fatal SVRD Head-ons	$20,918	$58,650	$24,000	$27,500	$848,800	$120,000	**$1,099,868**
PDO SDLD Sideswipes	N/A	$58,650	$24,000	$27,500	$0	$35,000	**$145,150**
Injury SDLD Sideswipes	$13,946	$58,650	$24,000	$27,500	$11,000	$45,000	**$180,096**
Fatal SDLD Sideswipes	$0	$58,650	$24,000	$27,500	$700,000	$120,000	**$930,150**
PDO ODLD Sideswipes	N/A	$58,650	$24,000	$27,500	$0	$35,000	**$145,150**
Injury ODLD Sideswipes	$13,946	$58,650	$24,000	$27,500	$14,000	$45,000	**$183,096**
Fatal ODLD Sideswipes	$0	$58,650	$24,000	$27,500	$711,000	$120,000	**$941,150**

Table 43. Cost Estimates per Lane Departure Crash by Crash Severity with High-Value Cargo Damages of $1,000,000

Crash Type and Severity	Labor and Workers' Comp.	Operational	Environ-mental	Property Damage	Legal Settlement	Court Costs and Other Legal Fees	Total
PDO SVRD Collisions	N/A	$1,011,450	$35,000	$34,167	$0	$40,000	**$1,120,617**
Injury SVRD Collisions	$62,755	$1,011,450	$35,000	$34,167	$132,000	$60,000	**$1,335,372**
Fatal SVRD Collisions	$62,755	$1,011,450	$35,000	$34,167	$922,000	$170,000	**$2,235,372**
PDO SVRD Rollovers	N/A	$1,013,625	$82,500	$55,833	$0	$30,000	**$1,181,958**
Injury SVRD Rollovers	$69,728	$1,013,625	$82,500	$55,833	$184,250	$35,000	**$1,440,936**
Fatal SVRD Rollovers	$69,728	$1,013,625	$82,500	$55,833	$700,000	$110,000	**$2,031,686**
PDO SVRD Head-ons	N/A	$1,008,650	$24,000	$27,500	$0	$40,000	**$1,100,150**
Injury SVRD Head-ons	$6,973	$1,008,650	$24,000	$27,500	$130,200	$45,000	**$1,242,323**
Fatal SVRD Head-ons	$20,918	$1,008,650	$24,000	$27,500	$848,8000	$120,000	**$2,049,868**
PDO SDLD Sideswipes	N/A	$1,008,650	$24,000	$27,500	$0	$35,000	**$1,095,150**
Injury SDLD Sideswipes	$13,946	$1,008,650	$24,000	$27,500	$11,000	$45,000	**$1,130,096**
Fatal SDLD Sideswipes	$0	$1,008,650	$24,000	$27,500	$700,000	$120,000	**$1,880,150**
PDO ODLD Sideswipes	N/A	$1,008,650	$24,000	$27,500	$0	$35,000	**$1,095,150**
Injury ODLD Sideswipes	$13,946	$1,008,650	$24,000	$27,500	$14,000	$45,000	**$1,130,096**
Fatal ODLD Sideswipes	$0	$1,008,650	$24,000	$27,500	$711,000	$120,000	**$1,891,150**

Following the same methodology described in the previous sections, the average crash costs for high-value cargo carriers are presented below in Table 44 and Table 45.

Table 44. Anticipated Benefits per Dollar Spent for Purchasing LDWS per Crash Avoided for an Average Annual VMT of 100,000 VMT, 3% Discount Rate with Financing

High-Value Cargo Damages	Low Efficacy	High Efficacy
$50,000	$2.18	$4.61
$1,000,000	$11.67	$24.33

Table 45. Anticipated Benefits per Dollar Spent for Purchasing LDWS per Crash Avoided for an Average Annual VMT of 100,000 VMT, 7% Discount Rate with Financing

High-Value Cargo Damages	Low Efficacy	High Efficacy
$50,000	$2.11	$4.47
$1,000,000	$11.32	$23.60

Since the crash costs are greater for high-value cargo carriers, the benefits that accrue from the crash-avoidance technology are greater as well.

6. FINDINGS AND CONCLUSIONS

The following findings and conclusions were derived from this economic analysis of LDWS for large trucks.

Using low and high estimates of efficacy rates ranging from 23 percent to 53 percent, it was estimated that the LDWS has the potential to prevent approximately 1,069–2,463 SVRD collisions, 627–1,307 SVRD rollovers, 1,111–2,223 SDLD sideswipes, 997–1,992 ODLD sideswipes, and 59–118 ODLD head-ons.

Based on the average estimates of typical individual crash costs, the PDO crashes range in cost from $100,150–$196,958, injury crashes are in the range of $135,096–$455,936, and fatal crashes are in the range of $885,150–$1,252,872. These costs reflect the direct out-of-pocket costs for motor carriers that have deductibles at or above crash costs, or are self-insured. However, any trucking industry stakeholder that is a party to crash cost calculations or liability—such as insurers, legal defense firms, or industry suppliers—can use the figures to understand the safety impacts of onboard safety systems.

The cost estimates are based on currently available motor carrier, insurance, and supplier information on the actual expenses incurred by the motor carrier industry in crashes that could be prevented by the use of LDWS.

Regardless of the average VMTs traveled, medium to large motor carriers with an average likelihood of being involved in a lane departure crash will achieve positive returns on investment by purchasing and using LDWS. Based on the cost and crash scenarios used herein, many carriers investing in the LDWS will achieve a higher return on investment than those that do not invest in the system.

The sensitivity analysis further demonstrates that even small carriers, which generally will not incur the same per-truck crash costs as larger carriers, can realize added benefits related to insurance implications if one or more crashes are prevented using LDWS.

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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 (USDOT) 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 in these sites; during each visit, the data collectors collect all police traffic accident reports (PARs) and then select a sample of these reports. An 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."

The PARs from which GES data files are coded 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."

The main limitation of using GES as a data source is that when looking at extremely specific crash types, there is a possibility that a query will return a small number of records, since the actual number of crashes that each record represents is given by a weight.

The data fields and variables that were used in this analysis are presented in Table 46.

Table 46. GES Fields and Variables Defining Crashes Addressed by LDWS

Field Name	Variables for SVRD Collisions with Fixed Object	Variables for SVRD Rollovers	Variables for SDLD Sideswipes	Variables for ODLD Sideswipes	Variables for ODLD Head-ons
Body Type BODY_TYP (V05)	64—Straight Truck 66—Truck Tractor 78—Unknown Medium/Heavy Truck	64—Straight Truck 66—Truck Tractor 78—Unknown Medium/Heavy Truck	64—Straight Truck 66—Truck Tractor 78—Unknown Medium/Heavy Truck	64—Straight Truck 66—Truck Tractor 78—Unknown Medium/Heavy Truck	64—Straight Truck 66—Truck Tractor 78—Unknown Medium/Heavy Truck
Most Harmful Event V_EVENT (V20)	Not 1 (Rollover/ Overturn)	1—Rollover/Overturn			
Movement Prior to Critical Event P_CRASH1 (V21)	1—Going Straight 2—Decelerating in Traffic Lane 14—Negotiating a Curve	1—Going Straight 2—Decelerating in Traffic Lane 14—Negotiating a Curve	1—Going Straight 2—Decelerating in Traffic Lane 14—Negotiating a Curve	1—Going Straight 2—Decelerating in Traffic Lane 14—Negotiating a Curve	1—Going Straight 2—Decelerating in Traffic Lane 14—Negotiating a Curve
Accident Type ACC_TYPE (V23)	1—Right Roadside Departure: Drive Off Road 2—Right Roadside Departure: Control/Traction Loss 6—Left Roadside Departure: Drive Off Road 7—Left Roadside Departure: Control/Traction Loss	1—Right Roadside Departure: Drive Off Road 2—Right Roadside Departure: Control/Traction Loss 6—Left Roadside Departure: Drive Off Road 7—Left Roadside Departure: Control/Traction Loss	44—Sideswipe/Angle: Straight Ahead on Left 45—Sideswipe/Angle: Straight Ahead on Right 46—Sideswipe/Angle: Changing Lanes to the Right 47—Sideswipe/Angle: Changing Lanes to the Left	64—Sideswipe/Angle: Lateral Move Left/Right	50—Head-On Lateral Move Left/Right

Field Name	Variables for SVRD Collisions with Fixed Object	Variables for SVRD Rollovers	Variables for SDLD Sideswipes	Variables for ODLD Sideswipes	Variables for ODLD Head-ons
Critical Event P_CRASH2 (V26)	12—Critical Event Initiated by This Vehicle Traveling Over Left Edge of Roadway 13—Critical Event Initiated by This Vehicle Traveling Over Right Edge of Roadway	12—Critical Event Initiated by This Vehicle Traveling Over Left Edge of Roadway 13—Critical Event Initiated by This Vehicle Traveling Over Right Edge of Roadway	10—Critical Event Initiated by This Vehicle Traveling Over the Lane Line on the Left Side of the Travel Lane 11—Critical Event Initiated by This Vehicle Traveling Over the Lane Line on the Right Side of the Travel Lane	10—Critical Event Initiated by This Vehicle Traveling Over the Lane Line on the Left Side of the Travel Lane 11—Critical Event Initiated by This Vehicle Traveling Over the Lane Line on the Right Side of the Travel Lane	10—Critical Event Initiated by This Vehicle Traveling Over the Lane Line on the Left Side of the Travel Lane
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]	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]	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]	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]	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	1—Driver of a Motor Vehicle 2—Passenger of a Motor Vehicle 9—Unknown Occupant	1—Driver of a Motor Vehicle 2—Passenger of a Motor Vehicle 9—Unknown Occupant	1—Driver of a Motor Vehicle 2—Passenger of a Motor Vehicle 9—Unknown Occupant	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 use 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 and straight trucks in the United States, 217,488 million miles averaged across years 2001–2005(Federal Highway Administration 2001–2005), is shown in Table 47.

Table 47. Average Annual VMT (millions of miles) for Combination Vehicles, 2001–2005

Truck Type	2001	2002	2003	2004	2005	Average
Combination and Straight Trucks	207,686	214,530	215,884	226,504	222,836	217,488

APPENDIX B: SUPPORTING DATA

This appendix contains the annual number of crashes, injuries, and fatalities for lane- departure crashes from 2001–2005, as presented in Table 48 through Table 57. 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 48. Annual Number of SVRD Collision PDO, Injury, and Fatal Crashes, 2001–2005

Crash Type	2001	2002	2003	2004	2005	Average
Number of PDO Crashes	2,878	4,206	4,177	2,870	3,878	3,602
Number of Injury Crashes	850	894	1,213	1,102	851	982
Number of Fatal Crashes	91	60	86	13	69	64

Table 49. Annual Number of SVRD Rollover PDO, Injury, and Fatal Crashes, 2001–2005

Crash Type	2001	2002	2003	2004	2005	Average
Number of PDO Crashes	976	1,415	1,347	1,255	736	1,146
Number of Injury Crashes	2,289	1,520	706	1,757	874	1,430
Number of Fatal Crashes	18	103	0	58	10	38

Table 50. Annual Number of SDLD Sideswipe PDO, Injury, and Fatal Crashes, 2001–2005

Crash Type	2001	2002	2003	2004	2005	Average
Number of PDO Crashes	6,444	3,235	5,167	3,275	3,220	4,268
Number of Injury Crashes	484	980	605	457	286	562
Number of Fatal Crashes	0	0	0	0	10	2

Table 51. Annual Number of ODLD Sideswipe PDO, Injury, and Fatal Crashes, 2001–2005

Crash Type	2001	2002	2003	2004	2005	Average
Number of PDO Crashes	3,967	5,874	3,822	2,670	2,352	3,737
Number of Injury Crashes	528	852	478	307	618	557
Number of Fatal Crashes	2	4	161	12	6	37

Table 52. Annual Number of ODLD Head-on PDO, Injury, and Fatal Crashes, 2001–2005

Crash Type	2001	2002	2003	2004	2005	Average
Number of PDO Crashes	211	16	257	0	4	98
Number of Injury Crashes	106	12	233	10	112	95
Number of Fatal Crashes	8	10	95	203	0	63

Table 53. Annual Number of Injuries and Fatalities in SVRD Collisions, 2001–2005

Crash Statistic	2001	2002	2003	2004	2005	Average
Injuries in Injury Crashes	954	1,173	1,236	1,148	924	1,087
Fatalities in Fatal Crashes	91	60	166	17	69	81
Injuries in Fatal Crashes	16	23	0	0	0	8
Number Truck Driver Injuries	732	910	1,192	938	797	914
Number Truck Driver Fatalities	83	50	86	13	69	60

Table 54. Annual Number of Injuries and Fatalities in SVRD Rollovers, 2001–2005

Crash Statistic	2001	2002	2003	2004	2005	Average
Injuries in Injury Crashes	2,612	1,732	841	2,090	876	1,630
Fatalities in Fatal Crashes	18	103	0	58	10	38
Injuries in Fatal Crashes	0	0	0	0	0	0
Number Truck Driver Injuries	2,277	1,486	611	1,749	867	1,398
Number Truck Driver Fatalities	18	103	0	58	10	38

Table 55. Annual Number of Injuries and Fatalities in SDLD Sideswipes, 2001–2005

Crash Statistic	2001	2002	2003	2004	2005	Average
Injuries in Injury Crashes	543	1,041	718	557	340	640
Fatalities in Fatal Crashes	0	0	0	0	10	2
Injuries in Fatal Crashes	0	0	0	0	0	0
Number Truck Driver Injuries	10	365	96	14	7	98
Number Truck Driver Fatalities	0	0	0	0	0	0

Table 56. Annual Number of Injuries and Fatalities in ODLD Sideswipes, 2001–2005

Crash Statistic	2001	2002	2003	2004	2005	Average
Injuries in Injury Crashes	557	1,356	730	365	799	761
Fatalities in Fatal Crashes	2	8	161	12	6	38
Injuries in Fatal Crashes	4	4	161	24	9	40
Number Truck Driver Injuries	54	3	465	22	46	118
Number Truck Driver Fatalities	2	0	0	0	2	1

Table 57. Annual Number of Injuries and Fatalities in ODLD Head-ons, 2001–2005

Crash Statistic	2001	2002	2003	2004	2005	Average
Injuries in Injury Crashes	117	25	393	10	116	132
Fatalities in Fatal Crashes	8	10	95	203	0	63
Injuries in Fatal Crashes	8	30	190	286	0	103
Number Truck Driver Injuries	0	22	0	44	5	14
Number Truck Driver Fatalities	8	0	95	0	0	21

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

Part 1: Carrier Interview Guide begins on the next page.

Part 2: Survey Respondent Demographics follows.

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 environmental costs other than the ones mentioned above?
Yes ❑ No ❑

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

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 occur.

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 D: ACKNOWLEDGMENTS

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