# Analysis of
# Benefits and Costs
# of
# Forward Collision 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 for CMVs to enhance the safety of all roadway users.

The purpose of this document is to provide economic benefits, expected costs, and industry returns on investment for forward collision warning systems described herein. Verification of the costs and benefits of safety systems is critical for facilitating voluntary acceptance of these systems within 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 been 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 (SAFETEA-LU) of 2005, which states, "Any survey, questionnaire, or interview that the Secretary considers necessary to carry out the evaluation of any test or program assessment activity under this subchapter shall not be subject to chapter 35 of title 44."

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16. Abstract

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

**The purpose of this report is to evaluate costs and benefits for industry associated with Forward Collision Warning Systems that can reduce large truck rear-end crashes.**

**The analysis described herein indicates that Forward Collision Warning Systems on combination and single-unit vehicles will help to prevent rear-end 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

| | |
|---|---|
| ABS | Anti-Lock Braking System |
| ACC | Adaptive Cruise Control |
| 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 |
| FCWS | Forward Collision Warning System |
| FMCSA | Federal Motor Carrier Safety Administration |
| FOT | Field Operational Test |
| GES | General Estimates System |
| HAZMAT | Hazardous Materials |
| IVI | Intelligent Vehicle Initiative |
| MARCS | Modified Accelerated Cost Recovery System |
| NASS | National Sampling Automotive System |
| NHTSA | National Highway Traffic Safety Administration |
| OEM | Original Equipment Manufacturer |
| OMB | U.S. Office of Management and Budget |
| OSS | Onboard Safety System |
| PAR | Police Traffic Accident Report |
| PDO | Property Damage Only |
| USDOT | United States Department of Transportation |
| VMT | Vehicle Miles Traveled |
| WC | Workers' Compensation |

# 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 encourage the deployment of several onboard safety systems (OSS) for CMVs in an effort to enhance the safety of all roadway users.

As part of an ongoing FMCSA effort to encourage voluntary adoption of onboard safety systems, this analysis builds on previous field operational testing by refocusing benefit-cost assessments from societal impacts to targeted motor carrier industry outcomes, since motor carriers are the end-users who 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 purchasing decisions of Forward Collision Warning Systems (FCWS). 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 FCWS from a motor carrier perspective. However, other industry stakeholders, such as insurance companies, vendors, and risk managers, can equally well apply the calculations to their own internal assessments and programs.

## TECHNOLOGY DESCRIPTION

FCWS provide audible and/or visual warnings of vehicles or objects that come within a predefined interval in front of the vehicle equipped with FCWS. To account for closing distance, the distance that triggers a warning varies based on settings cross-factored with the speed at which the driver is traveling. Systems currently on the market rely on Doppler-based radar that transmits and receives signals to determine distance, difference in relative speed, and azimuth between the large truck and the vehicle or object in front of it. When a large truck equipped with the FCWS approaches a slower-moving vehicle or stationary object, progressively more urgent warnings are issued from the system according to pre-set thresholds. These warnings are designed to improve driver behavior through targeted feedback about safe following distances.

FCWS may also be integrated with an adaptive cruise control (ACC) system, which automatically maintains a set following interval between the large truck and a vehicle in front of it. ACC systems interact with the truck's engine management system (transmission and throttle) and cruise control system to control the speed of the vehicle. As a result, FCWS with ACC have the potential to prevent rear-end collisions in which the truck is striking another vehicle; however, they do not automatically decelerate or stop the truck.

**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 a CMV crash. As a result, this assessment incorporates actual motor-carrier-based benefit-cost data.

The methodology for this analysis was based on estimates of crash cost avoidance for the primary type of crash that can be addressed by FWCS on straight trucks and combination vehicles. FCWS benefits were primarily based on reducing the occurrence of large-truck rear-end collisions in which the truck is striking another vehicle. To obtain a measure of crash cost avoidance, the number of crashes that the technology is estimated to prevent each year per vehicle miles traveled (VMT) was determined. Next, using information provided by motor carriers, insurance companies, legal experts, and others, the actual crash costs paid by the motor carrier industry were determined for large-truck rear-end collisions (i.e., trucks rear-ending other vehicles). As a result, trucking companies can use this cost information as a basis for evaluating the potential crash avoidance benefits of FCWS with the purchase and operational costs of this technology.

The motor carrier crash costs that may be fully avoided, or whose severity may be decreased, by the use of FCWS 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
- Property Damage and Auto Liability Costs
- Environmental Costs
  - Fines
  - Clean-up costs
- Legal Costs
  - Court costs
  - Legal fees
  - 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 greater than total crash costs, or by self-insured motor carriers. However, other industry stakeholders such as insurance companies, vendors, and risk managers can equally well apply the calculations to their own internal assessments and programs. The following findings and conclusions were derived from the benefit-cost analysis.

Using efficacy rates of 21 percent and 44 percent derived from a field test and industry input (see Section 3.1.2), it was estimated that between 8,597 and 18,013 rear-end crashes could be prevented through use of the FCWS. Based on the average estimates of the crash cost elements listed in the previous section, a property damage only (PDO) rear-end crash would cost $122,650, an injury rear-end crash would cost $239,063, and a fatal rear-end crash would cost $1,056,221. These avoided costs or benefits of the FCWS were based on a typical or median-cost 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 FCWS 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 FCWS 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 FCWS equipment. These total costs ranged from approximately $1,415 to $1,843.

The net present values of the FCWS 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 FCWS 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 $1.33 to $7.22 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 FCWS. These payback periods ranged from eight to 37 months, depending on the different VMTs, system efficacy estimates, 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, due to discrete differences in their financial and operating environments. For instance, small carriers are unlikely to be self-insured; therefore, out-of-pocket costs per crash will initially be much lower for small carriers. Since the median deductible for a motor carrier will fall in the $5,000–$50,000 range, these low and high deductibles were considered as part of the benefit and cost analysis.

Based on the overall probability of involvement in a rear-end crash, small carriers that have lower deductibles, such as $5,000 per truck, may not achieve a break-even point— a dollar or more of benefits for each dollar spent on financing the technology—in the first five years. However, as the number of crashes and/or their severity increases, insurance premium costs will increase until the carrier's insurance costs equal or exceed the investment costs of the FCWS, 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. Forward Collision Warning Systems (FCWS) are a type of commercially available onboard safety technology designed to prevent rear-end crashes.

In 2006, the U.S. Department of Transportation (USDOT) completed an independent evaluation of the Volvo Intelligent Vehicle Initiative (IVI) Field Operational Test (FOT) (Battelle 2007). The report included a societal benefit-cost analysis over a 20-year period of deployment for an FCWS designed to prevent rear-end crashes, both individually and as part of a bundled system which included adaptive cruise control (ACC) and advanced electronic braking systems. 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.

As part of an ongoing FMCSA effort to encourage voluntary adoption of FCWS, this benefit-cost analysis (BCA) 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 who are responsible for investment and deployment of the technology. The purpose of this BCA is to provide cost and return on investment information to the motor carrier industry in support of future decisions to purchase FCWS. The motor carrier industry has confirmed that verifying associated costs and benefits of safety systems is critical for spurring deployment, since these systems must prove to be beneficial, cost-effective investments that meet the users' needs.

## 1.1 TECHNOLOGY DESCRIPTIONS

FCWS provide audible and/or visual warnings of vehicles or objects that come within a predefined interval in front of the vehicle equipped with the FCWS. To account for closing distance, the distance that triggers a warning varies according to the speed at which the driver is traveling. Systems currently on the market rely on Doppler-based radar that transmits and receives signals to determine the distance, difference in relative speed, and azimuth between the large truck and the vehicle or object in front of it. When a large truck equipped with FCWS approaches a slower-moving vehicle or stationary object, a series of progressively more urgent warnings are issued from the system, according to pre-set thresholds. These warnings are designed to improve driver behavior through targeted feedback to drivers about safe following distances.

FCWS may also be integrated with ACC, which automatically maintains a set following interval between the large truck and a vehicle in front of it. ACC systems interact with the truck's engine management system (transmission and throttle) and cruise control system to manage the speed of the vehicle. As a result, FCWS with ACC has the potential to prevent rear-end collisions in which the truck strikes another vehicle; however, they do not automatically stop the truck. Furthermore, ACC systems are designed to engage only at a set speed threshold, typically greater than 35 mph. Next-generation systems now in development will use direct braking as an extended benefit of FCWS.

## 1.2 VOLVO FIELD OPERATIONAL TEST

The 2007 Volvo FOT evaluation showed that the FCWS with ACC reduced the risk of a rear-end collision by approximately 21 percent and helped drivers maintain longer following distances between their vehicle and a vehicle in front. As a result, FCWS were shown to be effective in situations in which a rear-end crash could result, since FCWS provide advance information that the driver could use to avoid a potential hazard.

The Volvo FOT report included a societal benefit-cost analysis over a 20-year deployment period of a FCWS preventing rear-end crashes. Societal costs include many factors, such as the lost productivity of commuters caught in traffic congestion resulting from truck crashes, or costs of emergency response personnel responding to crashes. However, avoiding these societal costs does not immediately translate into bottom-line cost savings for motor carriers purchasing onboard safety systems.

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

## 1.3 BENEFIT-COST ANALYSIS ASSUMPTIONS

Large-truck crashes often involve a complex series of critical events and factors, many of which can be mitigated through the use of OSS. However, crash reduction also depends on motor carrier factors which may not be directly addressed by OSS, such as operational characteristics, back-room safety initiatives, motor carrier safety “culture,” and driver selection, training, and management practices (Short et al. 2007). As a result of varying degrees of success in addressing these motor carrier factors, the levels of crash reduction and cost savings realized from the implementation of FCWS 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 customers they serve. Segmentation of the trucking industry is often based on the size of fleets, vehicle configurations, geographic range of operations, and commodities hauled. Usually one characteristic is not sufficient 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 vehicle miles traveled (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 50–100-mile radius of their base of operations. Combination vehicles are more often used in regional and long-distance applications, accounting for approximately 30 percent of all commercial vehicles and 65 percent of commercial 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 rear-end crashes can occur along any route, many fleet types may benefit from using FCWS. These systems can be installed on any truck configuration, including combination or single-unit vehicles. Yet they may be most promising for trucks with high mileage accumulated over their operational lives, which travel primarily at highway speeds.

# 2. BENEFIT-COST ANALYSIS STEPS

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

## 2.1 BENEFITS IN TERMS OF CRASH AVOIDANCE

### Step 1: Estimate Crashes Preventable by FCWS

Crash data in the General Estimates System (GES) were used to estimate the number of rear-end crashes in which the large truck was the striking vehicle that could be reduced over a five-year period, 2001–2005, by using FCWS on large trucks. These data were used to estimate the costs for rear-end crashes involving property damage only (PDO), injuries, and fatalities. Then, using information from motor carriers, suppliers, and the FOT, efficacy rates were calculated and used to estimate the portion of these crash types that could be prevented by FCWS.

### Step 2: Estimate the Crash Costs for the Crashes Preventable by FCWS

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 six major areas:

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

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

### 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 FCWS, and Step 2 provides estimates of the costs of those crashes, motor carriers need to know the cost-reduction value of the avoided crashes that they can expect through the use of FCWS. As a result, this step involves estimating crash avoidance costs based on VMT, and the expected crash reductions resulting from deployment of FCWS. To address variance in the average vehicle miles traveled by carriers in different operating conditions, the crash costs were calculated for annual VMT values of 80,000, 100,000, 120,000, 140,000, and 160,000 miles. 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 the Technology and Deployment Costs

The technology and deployment cost estimates for the FCWS 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 these costs, as well as Federal tax savings due to depreciation of the FCWS equipment.

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

## 2.3 BENEFIT-COST ANALYSIS CALCULATIONS

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

The net present value of the FCWS was computed by discounting future benefits and costs for the values in Steps 3 and 4 using discount rates of 3 and 7 percent. Discounting benefits and costs transforms gains and losses occurring in different time periods to a common unit of measurement. These values were calculated over the first five years of deployment, since estimates of product lifecycles are extremely 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 FCWS.

### 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 BCA used to determine the benefits of avoiding crashes preventable through the use of FCWS.

## 3.1 STEP 1: ESTIMATE CRASHES PREVENTABLE BY THE FCWS

The first step in this benefit-cost analysis involved estimating the number of annual crashes that are potentially preventable using FCWS. This estimation was based on crash data, Volvo FOT results, and motor carrier information.

### 3.1.1 Crash Data

Crash data in the GES were used to estimate the number of rear-end crashes in which the truck is the striking vehicle that could be reduced over a five-year period, 2001–2005, if FCWS were installed on large trucks (NHTSA 1988–2005). These data were used as the basis for estimating costs for rear-end collisions involving PDO, injuries, and/or fatalities.

Table 1 provides the crash data for the different rear-end-crash degrees of severity addressed by the FCWS.* 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. Annual crash data are presented in **Appendix C**. Since GES is a probability-based nationally representative sample of all police-reported fatal, injury, and property-damage-only crashes, 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 rear-end crashes for large trucks resulting in fatal, injury, or PDO crashes. 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 Rear-End Crashes by Crash Severity, 2001–2005**

| PDO Crashes | Injury Crashes | Fatal Crashes | Total |
|---|---|---|---|
| 27,681 | 13,022 | 235 | **40,938** |

### 3.1.2 Efficacy of FCWS

While the crashes presented in Table 1 represent the average numbers of crashes potentially preventable by FCWS, the technology will not generally prevent all of these crashes. For example, FCWS will not prevent crashes that are initiated by major vehicle mechanical failures, such as faulty brakes, steering loss, or tire blowouts, which may have been included in this data set. If another vehicle suddenly cut in front of a truck so that the driver did not have time to react

* Approximately half of these crashes involved combination vehicles (19,884 combination vehicles out of a total of 40,938 combination vehicles and straight trucks).

to the warning of the FCWS, the crash would not likely be prevented. Finally, these systems would have limited effectiveness in rear-end crashes that occur when the truck drivers are incapacitated, seriously ill, or unconscious.

Efficacy rates or crash prevention rates represent the percentage of crashes that FCWS would have a high probability of preventing. Using information from the Volvo 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 FCWS. The range of efficacy rates estimated by different industry sources varied from 21 percent (Volvo FOT estimate) to 44 percent (40 out of 91 rear-end crashes). For the high efficacy rate, motor carriers provided the average number of rear-end events that occurred annually and estimated the number of rear-end events that were preventable by the FCWS. The efficacy rates were calculated by dividing the number of crashes preventable by the technology by the sum of the number of crashes experienced and the number of crashes avoided. Multiplying the number of crashes in Table 1 by these efficacy rates resulted in the estimated number of crashes preventable by FCWS, as shown in Table 2.

**Table 2. Estimated Mean Annual Number of Crashes Preventable by FCWS by Crash Severity, 2001–2005**

| Efficacy Rate | PDO Rear-End Collisions | Injury Rear-End Collisions | Fatal Rear-End Collisions | Total |
|---|---|---|---|---|
| 21% Efficacy | 5,813 | 2,735 | 49 | **8,597** |
| 44% Efficacy | 12,180 | 5,730 | 103 | **18,013** |

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

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

### 3.2.1 Cost Data Collection Process

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

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

Baseline data were also received from respondents 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 during that period. 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 "The Costs of Truckload Driver Turnover" (Rodriguez et al. 2000). All of the costs obtained from these interviews were assumed to be in 2007-year dollars.

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

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

After the ranges were identified for the six data collection cost categories, median costs were determined. While there was little deviation between mean and median cost calculations, occasional outliers were evident in certain categories. For instance, rare jury decisions have resulted in single-fatality settlements exceeding $10 million, but these are extremely infrequent occurrences. Since these outlying responses were not representative of the sample as a whole and would have negatively influenced the calculation of a "typical" crash cost, median values were used instead. The interview respondents were also asked how the potential crash costs presented might be impacted 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 costs estimates related to the training, testing, hiring, and orientation activities when a new driver is brought into the organization. Training costs included any ancillary tuition, instructor costs, and team-driver costs. Testing costs included a driver background check, drug screening tests, and physicals (medical exams). Hiring costs included any bonuses and relocation costs provided to new hires. When provided by carriers, orientation costs included items such as meals and lodging expenses. Table 3 presents a breakout of these median costs per each new driver hired—costs provided by the interviewed carriers and insurance companies.

**Table 3. Median Driver Replacement Cost Elements 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 the hardships associated with injuries 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 cost for hospitals, doctors, medical treatment, etc.

Disability Pay—pays temporarily while the employee is getting back to normal, or permanently if the employee is unable to return to work. The amount varies, but can be as high as one-half to two-thirds of normal pay.

Vocational Rehabilitation—covers cases in which the injury renders the employee unable to perform the usual duties of his or her occupation; includes re-training to enter into 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 can be borne by motor carriers if they are not self-insured, and the remainder is covered by insurance, as required. In order to isolate 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 involved in an accident is the party that is injured or killed. To accurately account for the actual labor costs associated with truck crashes as well as the cost savings that can be expected from the use of FCWS, labor costs were multiplied by the average number of injuries and fatalities that were incurred by truck drivers on a per-crash basis. As shown in Table 4, on average, 10 percent of truck drivers are injured in rear-end crashes that involve an injury, and 40 percent of truck drivers are killed in rear-end crashes that involve a fatality.

**Table 4. Average Annual Numbers of Truck Driver Injuries and Fatalities per Rear-End Crash, 2001–2005**

| Rear-End Crash Type | Number of Crashes | Number of Injuries in Crashes | Number of Injuries per Crash | Number of Fatalities in Crashes | Number of Fatalities per Crash |
|---|---|---|---|---|---|
| Injury Crashes | 13,022 | 1,542 | 0.1 | N/A | N/A |
| Fatal Crashes | 235 | 0 | 0 | 88 | 0.4 |

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

**Table 5. Average Labor and Workers' Compensation Cost Elements per Rear-End Injury or Fatal Crash**

| Cost Category | Injury Crash | Fatality Crash |
|---|---|---|
| Driver Replacement | $700 | $2,800 |
| Workers' Compensation | $6,273 | $25,091 |
| **Total** | **$6,973** | **$27,891** |

### 3.2.4 Operational Costs

Operational costs considered in this analysis included cargo damage, delivery delays, and loading and unloading, as well as towing, inventory, storage, and other miscellaneous costs. Table 6 presents information on categories of typical median operational costs which the interviewed carriers provided about what they typically pay in the event of a rear-end crash. Cargo damage costs, which can include extreme ranges relating to cargo value, included direct median damage claims 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 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 with 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.

Median operational costs per crash are shown in Table 6. Overall operational costs were estimated to be approximately $11,150 for rear-end crashes, but these total costs could vary substantially, depending primarily on the value of damaged cargo.

**Table 6. Median Operational Costs per Rear-End Crash**

| Cost Category | Cost |
|---|---|
| Cargo damage | $2,500 |
| Cargo delivery delays | $750 |
| Loading and unloading cargo | $2,500 |
| Towing, inventory, and storage | $5,000 |
| Miscellaneous | $400 |
| **Total** | **$11,150** |

Additional operational costs considered for inclusion in this analysis were citations and penalties resulting from crashes. Rear-end crashes may involve fines for such citations as driving too fast for conditions. A collection of information from state and local authorities from 10 states and seven cities indicated that the average penalty for these types of fines is approximately $140. Since violation citations are not cited 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 clean-up of impacted water ranged from $500 to over $100,000 per crash, depending on the type of waterway involved. If a body of water was not impacted, the clean-up costs ranged from $300 to over $20,000 per crash. The variability in both ranges—water impacted and no water impacted—depended on what type of substance was leaked or spilled, and the amount involved.

When estimated by the carriers, out-of-pocket costs for environmental clean-up depended on the crash type but represented actual costs to the carrier. For a rear-end crash, the interviewed carriers estimated a median cost of $10,000 per crash, including fees paid to an environmental clean-up company.

In addition to these costs, a carrier may be required to pay fines for any environmental damage. The costs of these fines also vary 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 is impacted is $4,000; the average environmental fine for a crash in which water is impacted is $7,500. For this analysis, the conservative figure of $4,000 is being used as the environmental fine per crash. The total environmental clean-up cost used in this analysis is $14,000.

### 3.2.6 Property Damage Costs

Median costs for property damage in crashes as provided by the interviewed insurers and carriers for rear-end crashes are presented in Table 7. Infrastructure and surrounding structural damage refer to the damage from the crash 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, PDO refers specifically to the vehicular damage to the truck.

**Table 7. Median Property Damage Costs per Rear-end Crash**

| Cost Category | Cost |
|---|---|
| PDO to truck | $25,000 |
| Damages caused to structures other than the truck | $2,500 |
| **Total** | **$27,500** |

### 3.2.7 Legal Costs

According to information collected from 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 8 for each type of rear-end crash

**Table 8. Average Legal Fees and Court Costs per Rear-End Crash**

| Cost Category | PDO | Injury | Fatal |
|---|---|---|---|
| Legal Fees | $20,000 | $40,000 | $150,000 |
| Court Costs | $50,000 | $50,000 | $50,000 |
| **Total** | **$70,000** | **$90,000** | **$200,000** |

The out-of-pocket settlement costs are expenses paid to claimants, including punitive and compensatory damages. The median settlement cost per fatality is $700,000. The average settlement cost per injury was calculated by a weighted average of the percentage of the incapacitating injuries multiplied by the highest settlement cost of $500,000 for injuries in a range of settlement costs for rear-end crashes, added to the percentage of non-incapacitating injuries multiplied by the lowest settlement cost of $10,000 for injuries in a range of settlement costs for injuries. According to the GES data, approximately 12 percent of the rear-end crashes estimated to be preventable by FCWS resulted in incapacitating injuries, while 88 percent resulted in non-incapacitating injuries. As a result, the weighted average cost of an injury in a rear-end crash preventable by FCWS is $68,800.

For this analysis, the costs per injury or fatality depended on the average number of injuries and fatalities in crashes preventable by the FCWS. GES data provided the numbers of injuries and fatalities in the crashes preventable by the FCWS, 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 9 presents these results. A detailed summary of the numbers of injuries and fatalities per year in rear-end crashes is provided in Appendix C.

**Table 9. Average Annual Numbers of Injuries and Fatalities per Rear-End Crash, 2001–2005**

| Rear-End Crash Type | Number of Crashes | Number of Injuries in Crashes | Number of Injuries per Crash | Number of Fatalities in Crashes | Number of Fatalities per Crash |
|---|---|---|---|---|---|
| Injury Crashes | 13,022 | 16,676 | 1.3 | N/A | N/A |
| Fatal Crashes | 235 | 267 | 1.1 | 241 | 1 |

Table 10 shows the median cost per injury crash and per fatality crash involving a rear-end crash preventable by the FCWS. These results were obtained by multiplying the annual average numbers of fatalities and/or injuries per crash type in Table 9 by the settlement costs of, respectively, $700,000 for one fatality and $68,800 for one injury.

**Table 10. Average Settlement Costs per Injury and Fatal Rear-End Crash**

| Cost Category | Injury | Fatal |
|---|---|---|
| Out-of-Pocket Costs per Injury | $89,440 | $75,680 |
| Out-of-Pocket per Fatality | | $700,000 |
| **Total** | **$89,440** | **$775,680** |

### 3.2.8 Summary of Total PDO Crash, Injury Crash, and Fatal Crash Costs for Rear-End Crashes

Based on the median cost estimates from the previous subsections, Table 11 summarizes the major crash costs for rear-end collisions which could have been avoided through the use of FCWS. These costs are based on a typical or average incident; therefore, they should be interpreted as approximations of typical expected values.

**Table 11. Cost Estimates per Rear-End Crash, by Crash Severity**

| Cost Category | PDO | Injury | Fatality |
|---|---|---|---|
| Labor and Workers' Compensation | N/A | $6,973 | $27,891 |
| Operational | $11,150 | $11,150 | $11,150 |
| Environmental | $14,000 | $14,000 | $14,000 |
| Property Damage | $27,500 | $27,500 | $27,500 |
| Legal Settlement | | $89,440 | $775,680 |
| Court Costs and Other Legal Fees | $70,000 | $90,000 | $200,000 |
| **Total** | **$122,650** | **$239,063** | **$1,056,221** |

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 (49 CFR 387) requirements, all motor carriers must, at minimum, either insure their equipment for crash liability and cargo damage or demonstrate the financial capacity to cover liability and cargo damage costs for all of their trucks (USDOT 2001). FMCSA will consider and approve, subject to appropriate and reasonable conditions, the application of a motor carrier to qualify as a self-insurer, if the carrier furnishes a true and accurate statement of its financial condition and other evidence that establishes to the satisfaction of the FMCSA the motor carrier's ability to satisfy its obligation for coverage of bodily injury liability, property damage liability, or cargo liability. In the case of a crash, it is likely that a self-insured carrier would assume all of the costs summarized in Table 11.

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

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

Due to the high cost of truck crashes, major truck insurance providers and various truck fleets indicated that premiums are a significant business expense that most fleets would like to reduce. Yet, it should be noted that it is difficult to 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 approximately 8 to 15 percent increase in premiums 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 FCWS, and Step 2 provides estimates of the costs of those crashes, motor carriers ultimately need to know the crash cost savings they can expect through use of FCWS. As a result, Step 3 involves estimating crash avoidance costs based on vehicle miles traveled and expected crash reduction from deploying FCWS.

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 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.

To determine the costs of crashes preventable by FCWS for the various annual VMT values shown in Table 12 and Table 13, the first step involved dividing the estimated mean annual number of crashes preventable by FCWS from Table 2 by the mean annual total number of VMT for combination and single-unit trucks in the United States, averaged across years 2001–2005 (Federal Highway Administration 2001–2005) of 217,488 million miles. The resulting values were multiplied by annual VMT values of 80,000, 100,000, 120,000, 140,000, and 160,000 miles. The total values in Table 12 and Table 13 provide an estimate of the expected value of crash costs that can be avoided through the use of FCWS at different efficacy rates and VMTs. The resulting expected total costs are the sum of the probability of each possible outcome of the crashes preventable by FCWS multiplied by its estimated cost. Each total cost value represents the average annual amount one "expects" for the cost of each crash per vehicle at a different average VMT, with identical odds repeated many times for each VMT category.

**Table 12. Average Annual Crash Costs per Crash Avoided for an Average Annual VMT at 21% Efficacy**

| Average VMT | PDO | Injury | Fatal | Total Cost* |
|---|---|---|---|---|
| 80,000 | $262 | $241 | $19 | **$522** |
| 100,000 | $328 | $301 | $24 | **$652** |
| 120,000 | $393 | $361 | $29 | **$783** |
| 140,000 | $459 | $421 | $33 | **$913** |
| 160,000 | $525 | $481 | $38 | **$1,044** |

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

**Table 13. Average Annual Crash Costs per Crash Avoided for an Average Annual VMT at 44% Efficacy**

| Average VMT | PDO | Injury | Fatal | Total Cost* |
|---|---|---|---|---|
| 80,000 | $550 | $504 | $40 | **$1,093** |
| 100,000 | $687 | $630 | $50 | **$1,367** |
| 120,000 | $824 | $756 | $60 | **$1,640** |
| 140,000 | $962 | $882 | $70 | **$1,913** |
| 160,000 | $1,099 | $1,008 | $80 | **$2,187** |

*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 Step 4 methodology and findings for the benefit-cost analysis, and focuses on determining the costs of purchasing and deploying FCWS. The technology and deployment cost estimates for FCWS included the technology purchasing price, maintenance costs, and cost of training drivers in the use of the technology. Purchases of the technology with and without financing were both considered in these costs.

## 4.1 STEP 4: ESTIMATE THE TECHNOLOGY AND DEPLOYMENT COSTS

In the United States, Eaton VORAD is a leading market vendor of forward collision warning systems for large trucks. A typical original equipment manufacturer (OEM) list price for FCWS is approximately $2,000, with an additional price of $300 for adaptive cruise control (ACC).

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

**Table 14. Cost of Technology, if Financed**

| Technology | Book Price | Year 1 | Year 2 | Year 3 | Total* |
|---|---|---|---|---|---|
| FCWS | $2,000 | $734.27 | $734.27 | $734.27 | **$2,202.80** |
| FCWS-ACC | $2,300 | $844.41 | $844.41 | $844.41 | **$2,533.22** |

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

It is noteworthy that motor carriers experience Federal tax savings due to depreciation of the FCWS 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[†]). FCWS installed by the OEM are considered part of the truck cab. Consequently, the technology is subject to the Federal excise tax; a depreciable life of three years was used to determine the tax savings, as shown in Table 15 (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 depreciated each year. The General Depreciation Class for a three-year recovery period was used to determine the depreciation of the FCWS. 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.

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[*] 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.

**Table 15. Federal Tax Savings due to Depreciation**

| Technology | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 |
|---|---|---|---|---|---|
| FCWS | -$233.31 | -$311.15 | -$103.67 | -$51.87 | $0 |
| FCWS-ACC | -$268.31 | -$357.82 | -$119.22 | -$59.65 | $0 |

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 assumed 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 on training a driver. The costs of trainers, manuals, and other training materials were excluded, since they are part of a carrier's typical training budget, or may be provided by the system supplier.

Motor carriers reported in interviews that maintenance of FCWS was minimal and that any maintenance was considered a normal operating expense. As a result, maintenance costs were considered negligible. As shown in Table 16, the total costs of the technology with the added training costs, less the Federal tax savings, are provided for both the financed and non-financed purchase options.

**Table 16. Total Costs of Technology Deployment with and without Financing**

| Technology | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Total* |
|---|---|---|---|---|---|---|
| FCWS | $1,789.69 | -$288.15 | -$80.67 | -$28.87 | $23.00 | **$1,415.00** |
| FCWS-ACC | $523.96 | $446.12 | $653.60 | -$28.87 | $23.00 | **$1,617.80** |
| FCWS (financed) | $2,054.69 | -$334.82 | -$96.22 | -$36.65 | $23.00 | **$1,610.00** |
| FCWS-ACC (financed) | $599.10 | $509.58 | $748.19 | -$36.65 | $23.00 | **$1,843.22** |

*Total 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 net present values of the FCWS and FCWS-ACC systems were computed by discounting future benefits and costs for the values in Steps 3 and 4, using discount rates of 3 and 7 percent 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 is 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 FCWS are shown in Table 17 and Table 18 at the low and high efficacy rates. The discounted costs of the FCWS and FCWS with ACC are shown in Table 19.

**Table 17. Net Present Value of the Benefits of FCWS/FCWS with ACC at 21% Efficacy**

| Average Annual VMT | 3% Discount Rate | 7% Discount Rate |
|---|---|---|
| 80,000 | $2,389.68 | $2,139.47 |
| 100,000 | $2,987.10 | $2,674.34 |
| 120,000 | $3,584.51 | $3,209.20 |
| 140,000 | $4,181.93 | $3,744.07 |
| 160,000 | $4,779.35 | $4,278.94 |

**Table 18. Net Present Value of the Benefits of FCWS/FCWS with ACC at 44% Efficacy**

| Average Annual VMT | 3% Discount Rate | 7% Discount Rate |
|---|---|---|
| 80,000 | $5,007.42 | $4,483.13 |
| 100,000 | $6,259.28 | $5,603.91 |
| 120,000 | $7,511.13 | $6,724.69 |
| 140,000 | $8,762.99 | $7,845.47 |
| 160,000 | $10,014.84 | $8,966.26 |

**Table 19. Net Present Value of the Costs of FCWS/FCWS with ACC, 3% and 7% Discount Rates**

| Technology | No Financing 3% | No Financing 7% | Financing 3% | Financing 7% |
|---|---|---|---|---|
| FCWS | $1,386.32 | $1,349.45 | $1,521.52 | $1,407.24 |
| FCWS-ACC | $1,578.47 | $1,537.72 | $1,733.95 | $1,604.18 |

When the anticipated costs and benefits of FCWS 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 the VMT categories used, starting at 80,000. 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 20, Table 21, Table 22, and Table 23 present the average benefits a motor carrier could expect to receive for each dollar invested in FCWS.

**Table 20. Anticipated Benefits per Dollar Spent for Purchasing Technology, 3% Discount Rate without Financing**

| Average Annual VMT | FCWS 21% Efficacy | FCWS 44% Efficacy | FCWS-ACC 21% Efficacy | FCWS-ACC 44% Efficacy |
|---|---|---|---|---|
| 80,000 | $1.72 | $3.61 | $1.51 | $3.17 |
| 100,000 | $2.15 | $4.52 | $1.89 | $3.97 |
| 120,000 | $2.59 | $5.42 | $2.27 | $4.76 |
| 140,000 | $3.02 | $6.32 | $2.65 | $5.55 |
| 160,000 | $3.45 | $7.22 | $3.03 | $6.34 |

**Table 21. Anticipated Benefits per Dollar Spent for Purchasing Technology, 7% Discount Rate without Financing**

| Average Annual VMT | FCWS 21% Efficacy | FCWS 44% Efficacy | FCWS-ACC 21% Efficacy | FCWS-ACC 44% Efficacy |
|---|---|---|---|---|
| 80,000 | $1.59 | $3.32 | $1.39 | $2.92 |
| 100,000 | $1.98 | $4.15 | $1.74 | $3.64 |
| 120,000 | $2.38 | $4.98 | $2.09 | $4.37 |
| 140,000 | $2.77 | $5.81 | $2.43 | $5.10 |
| 160,000 | $3.17 | $6.64 | $2.78 | $5.83 |

**Table 22. Anticipated Benefits per Dollar Spent for Purchasing Technology, 3% Discount Rate with Financing**

| Average Annual VMT | FCWS 21% Efficacy | FCWS 44% Efficacy | FCWS-ACC 21% Efficacy | FCWS-ACC 44% Efficacy |
|---|---|---|---|---|
| 80,000 | $1.57 | $3.29 | $1.38 | $2.89 |
| 100,000 | $1.96 | $4.11 | $1.72 | $3.61 |
| 120,000 | $2.36 | $4.94 | $2.07 | $4.33 |
| 140,000 | $2.75 | $5.76 | $2.41 | $5.05 |
| 160,000 | $3.14 | $6.58 | $2.76 | $5.78 |

**Table 23. Anticipated Benefits per Dollar Spent for Purchasing Technology, 7% Discount Rate with Financing**

| Average Annual VMT | FCWS 21% Efficacy | FCWS 44% Efficacy | FCWS-ACC 21% Efficacy | FCWS-ACC 44% Efficacy |
|---|---|---|---|---|
| 80,000 | $1.52 | $3.19 | $1.33 | $2.79 |
| 100,000 | $1.90 | $3.98 | $1.67 | $3.49 |
| 120,000 | $2.28 | $4.78 | $2.00 | $4.19 |
| 140,000 | $2.66 | $5.58 | $2.33 | $4.89 |
| 160,000 | $3.04 | $6.37 | $2.67 | $5.59 |

### 5.1.1 Payback Periods

Payback periods were also calculated to determine the length of time required to recover the initial investments made for the FCWS. Although the motor carrier can expect a positive return on investment by purchasing the technology, the amount of time it will take for a motor carrier to realize positive benefits after purchasing the system varies by the average VMT per truck and the type of the technology. Shorter payback periods reflect less funding risk. Yet 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 $1,415 for the FCWS and the expected return of $1,093 annually for a VMT of 80,000 at the maximum efficacy of 44 percent, the payback period would be $1,415 divided by $1,093, which equals 1.3 years or 16 months.

The payback periods are shown in Table 24. 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 24. Payback Period for Technologies in Months**

| Average Annual VMT | FCWS 21% Efficacy | FCWS 44% Efficacy | FCWS-ACC 21% Efficacy | FCWS-ACC 44% Efficacy |
|---|---|---|---|---|
| 80,000 | 33 | 16 | 37 | 18 |
| 100,000 | 26 | 12 | 30 | 14 |
| 120,000 | 22 | 10 | 25 | 12 |
| 140,000 | 19 | 9 | 21 | 10 |
| 160,000 | 16 | 8 | 19 | 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 FCWS should also include the consideration of indirect costs.

To gain a broader understanding of the importance of all crash costs to motor carriers, a convenience survey was delivered to motor carriers associated with the Commercial Vehicle Safety Alliance, the American Trucking Associations, 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 mimic the statistical distributions of the motor carrier industry at large, 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 Likert scale of 1 to 5, with 1 being "Not Very Significant" and 5 being "Very Significant." Table 25 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, safety ratings, public image, and employee morale, as true impacts to carriers. The fact that FCWS have the potential to address these important indirect costs can add to the benefits of purchasing these systems.

**Table 25. 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. Lastly, this Step 6 sensitivity analysis can also be applied for 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 to $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 rear-end crash with the insurance deductibles of $50,000 and $5,000 are shown in Table 26 and Table 27, 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 covered by small carriers 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. If environmental costs were not incurred in the crashes, these benefits would be even lower.

**Table 26. Cost Estimates per Rear-End Crash by Crash Severity with Insurance Deductible of $50,000**

| Cost Category | PDO | Injury | Fatal |
|---|---|---|---|
| Driver Replacement | N/A | $700 | $2,800 |
| Workers' Compensation | N/A | $627 | $2,509 |
| Operational—Cargo delivery delays | $750 | $750 | $750 |
| Operational—Loading and unloading cargo | $2,500 | $2,500 | $2,500 |
| Operational—Towing, inventory, and storage | $5,000 | $5,000 | $5,000 |
| Operational—Miscellaneous | $400 | $400 | $400 |
| Environmental | $14,000 | $14,000 | $14,000 |
| Insurance Deductible | $50,000 | $50,000 | $50,000 |
| **Total** | **$72,650** | **$73,977** | **$77,959** |

**Table 27. Cost Estimates per Rear-End Crash by Crash Severity with Insurance Deductible of $5,000**

| Cost Category | PDO | Injury | Fatal |
|---|---|---|---|
| Driver Replacement | N/A | $700 | $2,800 |
| Workers' Compensation | N/A | $627 | $2,509 |
| Operational—Cargo delivery delays | $750 | $750 | $750 |
| Operational—Loading and unloading cargo | $2,500 | $2,500 | $2,500 |
| Operational—Towing, inventory, and storage | $5,000 | $5,000 | $5,000 |
| Operational—Miscellaneous | $400 | $400 | $400 |
| Environmental | $14,000 | $14,000 | $14,000 |
| Insurance Deductible | $5,000 | $5,000 | $5,000 |
| **Total** | **$27,650** | **$28,977** | **$32,959** |

The total values in Table 28 and Table 29 provide an estimate of the expected value of crash costs that can be avoided through the use of FCWS 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 FCWS multiplied by its estimated cost. Each total cost value represents the average annual amount one could "expect" as the cost of the crash per vehicle at a common annual 100,000 VMT.

**Table 28. FCWS: Average Annual Crash Costs per Crash Avoided for an Average Annual VMT of 100,000 VMT at 21% Efficacy**

| Deductible | PDO | Injury | Fatal | Total Cost* |
|---|---|---|---|---|
| $5,000 | $74 | $36 | $1 | **$111** |
| $50,000 | $194 | $93 | $2 | **$289** |

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

**Table 29. FCWS: Average Annual Crash Costs per Crash Avoided for an Average Annual VMT of 100,000 VMT at 44% Efficacy**

| Deductible | PDO | Injury | Fatal | Total Cost* |
|---|---|---|---|---|
| $5,000 | $155 | $76 | $2 | **$233** |
| $50,000 | $407 | $195 | $4 | **$605** |

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

After determining the net present values of the costs and benefits of the FCWS, the anticipated benefits of purchasing the FCWS per dollar spent were calculated for 100,000 VMT; they are shown below in Table 30 and Table 31. It was assumed that most small carriers would finance the purchase of the technology; therefore, the present value of the financed costs of the FCWS, both without and with ACC, at 3 percent and 7 percent from Table 19 were used to determine the results.

**Table 30. Anticipated Benefits per Dollar Spent for Purchasing FCWS/FCWS-ACC per Crash Avoided for an Average Annual VMT of 100,000 VMT, 3% Discount Rate with Financing**

| Deductible | FCWS 21% Efficacy | FCWS 44% Efficacy | FCWS-ACC 21% Efficacy | FCWS-ACC 44% Efficacy |
|---|---|---|---|---|
| $5,000 | $0.33 | $0.70 | $0.29 | $0.61 |
| $50,000 | $0.87 | $1.82 | $0.76 | $1.60 |

**Table 31. Anticipated Benefits per Dollar Spent for Purchasing FCWS/FCWS-ACC per Crash Avoided for an Average Annual VMT of 100,000 VMT, 7% Discount Rate with Financing**

| Deductible | FCWS 21% Efficacy | FCWS 44% Efficacy | FCWS-ACC 21% Efficacy | FCWS-ACC 44% Efficacy |
|---|---|---|---|---|
| $5,000 | $0.32 | $0.68 | $0.28 | $0.59 |
| $50,000 | $0.84 | $1.76 | $0.74 | $1.55 |

Since many rear-end crashes involving large trucks may not include environmental costs, the benefits of the FCWS, both without and with ACC, at 3 percent and 7 percent would be even lower for carriers who are not self-insured than the values shown in Table 30 and Table 31. At an annual average 100,000 VMT, the benefits would range from $0.60 per dollar spent on FCWS at a 21 percent efficacy rate to $1.47 per dollar spent on FCWS at a 44 percent 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 a rear-end crash, 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 FCWS investment, or until the carrier is eventually dropped by the insurer. The formula for such a consequence varies by number of crashes, 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 rear-end crash is spread over the entire population of small 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 a rear-end 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 premium payment per truck will be approximately $4,000 annually 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, the average loss per power unit cannot exceed $2,618 to prevent a rate increase.

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 by covering a 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 rear-end 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 an FCWS unit is $1,610.00. If the purchase of this unit prevents a crash that would result in higher insurance premiums, it will save a motor carrier approximately $390 per power unit.

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 return on investment.

### 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. If the cargo damage costs range from $50,000 to $1,000,000, instead of an average of $2,500, the total estimated crash costs for rear-end crashes increase by $47,500 and $997,500, respectively, due to operational cost changes. The total crash costs accounting for these differences are shown in Table 32 and Table 33.

**Table 32. Cost Estimates per Rear-End Crash by Crash Severity with High-Value Cargo Damages of $50,000**

| Cost Category | PDO | Injury | Fatal |
|---|---|---|---|
| Labor and Workers' Compensation | N/A | $6,973 | $27,891 |
| Operational | $58,650 | $58,650 | $58,650 |
| Environmental | $14,000 | $14,000 | $14,000 |
| Property Damage | $27,500 | $27,500 | $27,500 |
| Legal Settlement | N/A | $89,440 | $775,680 |
| Court Costs and Other Legal Fees | $70,000 | $90,000 | $200,000 |
| **Total** | **$170,150** | **$286,563** | **$1,103,721** |

**Table 33. Cost Estimates per Rear-End Crash by Crash Severity with High-Value Cargo Damages of $1,000,000**

| Cost Category | PDO | Injury | Fatal |
|---|---|---|---|
| Labor and Workers' Compensation | N/A | $6,973 | $27,891 |
| Operational | $1,008,650 | $1,008,650 | $1,008,650 |
| Environmental | $14,000 | $14,000 | $14,000 |
| Property Damage | $27,500 | $27,500 | $27,500 |
| Legal Settlement | N/A | $89,440 | $775,680 |
| Court Costs and Other Legal Fees | $70,000 | $90,000 | $200,000 |
| **Total** | **$1,120,150** | **$1,236,563** | **$2,053,721** |

Following the same methodology described in the previous sections, the anticipated benefits of FCWS for carriers of high-value cargo are presented below in Table 34 and

Table 35.

**Table 34. Anticipated Benefits per Dollar Spent for Purchasing FCWS per Crash Avoided for an Average Annual VMT of 100,000 VMT, 3% Discount Rate with Financing**

| High-Value Cargo Damages | FCWS 21% Efficacy | FCWS 44% Efficacy | FCWS-ACC 21% Efficacy | FCWS-ACC 44% Efficacy |
|---|---|---|---|---|
| $50,000 | $2.53 | $5.30 | $2.22 | $4.65 |
| $1,000,000 | $13.83 | $28.98 | $12.14 | $25.43 |

**Table 35. Anticipated Benefits per Dollar Spent for Purchasing FCWS per Crash Avoided for an Average Annual VMT of 100,000 VMT, 7% Discount Rate with Financing**

| High-Value Cargo Damages | FCWS 21% Efficacy | FCWS 44% Efficacy | FCWS-ACC 21% Efficacy | FCWS-ACC 44% Efficacy |
|---|---|---|---|---|
| $50,000 | $2.45 | $5.13 | $2.15 | $4.50 |
| $1,000,000 | $13.39 | $28.05 | $11.75 | $24.61 |

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

# 6. FINDINGS AND CONCLUSIONS

The following findings and conclusions were derived from this economic analysis for FCWS.

The average costs of rear-end crashes are approximately $122,650, $239,063, and $1,056,221 for PDO crashes, injury crashes, and fatal crashes, respectively. 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 and industry suppliers—can use the figures to understand the safety impacts of onboard safety systems.

Regardless of the average VMTs traveled, motor carriers with a typical likelihood of being involved in a rear-end crash will achieve positive returns on investment by purchasing and using FCWS. Based on the cost and crash scenarios used herein, many carriers investing in FCWS will achieve a higher return on investment than those than those who 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 preventable using FCWS.

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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" (NHTSA 2005, 3).

The PARs that GES data files are coded from represent a probability sample of all police-reported crashes in the United States. Therefore, once the records of interest within GES are isolated, a weight must be applied to calculate estimates of national crash characteristics, including items such as the number of crashes of a specific type, or the number of injuries within that accident type. This weight is indicated by the "Weight" variable in each GES data file; this weight is "the product of the inverse of the probabilities of selection at each of the three stages in the sampling process" (NHTSA 2005, 7)

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

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* For this Appendix content, the term "accident" is maintained to preserve the integrity of the actual data derived from the GES fields and database.

**Table 36. GES Fields and Variables Defining Crashes Addressed by CWS**

| Field Name | Variables for Rear-End Collisions |
|---|---|
| Body Type<br>BODY_TYP (V05) | 64—Straight Truck<br>66—Truck Tractor<br>78—Unknown Medium/Heavy Truck |
| VEH_ROLE (V22) | 1—Striking |
| Accident Type<br>ACC_TYPE (V23) | 20—Rear-end, Stopped<br>24—Rear-end, Slowing<br>28—Rear-end, Decelerating<br>32—Rear-end, Specifics Other<br>33—Rear-end, Specifics Unknown |
| Critical Event<br>P_CRASH2 (V26) | Other Motor Vehicle In Lane:<br>50—Other vehicle stopped<br>51—Traveling in same direction with lower steady speed<br>52—Traveling in same direction while decelerating |
| Injury Severity<br>INJ_SEV (P09) | 0—No Injury<br>1—Possible Injury<br>2—Non-incapacitating Injury<br>3—Incapacitating Injury<br>4—Fatal Injury<br>5—Injured, Severity Unknown<br>9—Unknown—[assumed as no injury] |
| Person Type<br>PER_TYPE (P3Z) | 1—Driver of a Motor Vehicle<br>2—Passenger of a Motor Vehicle<br>9—Unknown Occupant |

## Federal Highway Statistics

Federal Highway Statistics publications are managed by the Federal Highway Administration's Office of Highway Policy Information. The Highway Statistics Series contains statistical information on a variety of highway usage topics including vehicle mileage. The highway data analyzed in the Highway Statistics Series are submitted by individual states and analyzed against previously submitted data to ensure accuracy. The total number of vehicle miles traveled (VMT) for combination and straight trucks in the United States, 217,488 million miles averaged acrn years 2001–2005, (Federal Highway Administration 2001–2005) is shown in Table 37.

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

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

# APPENDIX B: INTERVIEW GUIDE – MOTOR CARRIER AND VENDOR DATA ON FCWS EFFICACY AND RETURN ON INVESTMENT

## VENDOR INTERVIEW GUIDE*

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

**Name/Company:**

**Title:**

**Phone/E-mail:**

1. Which types of crashes does the forward collision warning system most likely prevent?
   - ❑ Rear-end collisions
   - ❑ Other: ________________________________________
   - ❑ Other: ________________________________________
   - ❑ Other: ________________________________________

2. Is adaptive cruise control standard with your system, or is it optional?
   - ❑ Standard
   - ❑ Optional

3. Recognizing that price information is sensitive, please indicate a price range for the forward collision warning systems you provide.

   $________________ to $ ______________

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

   $________________

* This information collection is covered by the Office of Management and Budget and Paperwork Reduction Act exemption for ITS-related surveys, questionnaires, and interviews defined in Section 5305, Title V, Subtitle C, paragraph (i) (2) of SAFETEA-LU (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."

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

   $_________________

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

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

   ________ Hours

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

   ________ Years

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

| Crash Type | Single Units | 5-Axle, Single Trailers | 5-Axle, Single Tank Trailers | 5-Axle, Single Flat Bed Trailers | 5-Axle, Double Trailers (Vans) | Longer Combination Vehicles |
|---|---|---|---|---|---|---|
| **Rear-End Collisions** | | | | | | |
| **Other:____________** | | | | | | |
| **Other:____________** | | | | | | |
| **Other:____________** | | | | | | |
| **Other:____________** | | | | | | |
| **Other:____________** | | | | | | |

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

**MOTOR CARRIER INTERVIEW GUIDE**

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

**Name/Company:**

**Title:**

**Phone/E-mail:**

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

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

| Truck Category | Number | Percent with Forward Collision Warning Systems Currently Installed | Year Expected 100% Installation |
|---|---|---|---|
| **Straight Trucks** | | | |
| **Tractors** | | | |

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

4. Does the forward collision warning system your company uses include adaptive cruise control?
   - ❑ Yes
   - ❑ No

5. Which types of crashes does the forward collision warning system most likely prevent?
   - ❑ Rear-end collisions
   - ❑ Other: _____________________________________
   - ❑ Other: _____________________________________
   - ❑ Other: _____________________________________

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

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

| Cost Category | Short-Term Staff Disruption | Cost of Driver Recruitment Marketing | Training Costs (i.e., School Costs, Instructor Costs) | Testing Costs (i.e., Background Checks, Physicals) | Hiring Costs (i.e., Bonuses, Training, and Relocation) | Orientation Costs | Total Costs |
|---|---|---|---|---|---|---|---|
| **Current Estimate** | No data | No data | $3,350 | $500 | $500 | $2,650 | $7,000 |
| **Your Estimate** | | | | | | | |

8. Recognizing that price information is sensitive, please indicate a price range for the forward collision warning system you use.

   $____________ to $ _______________

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

   $_____________

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

    $_____________

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

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

   a. How are drivers compensated for this time?

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

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

   $_____________ years

13. Please complete the following chart for trucks that are equipped with forward collision warning systems.

**Technology Type:** ____________________________________________

**Average Annual VMT per Truck:** ____________________________________________

**Average Number of Total Crashes Per Year:** ____________________________________________

| Crash Type | Average Number of Crashes Per Year | Estimated Number of Crashes Avoided with Technology Per Year | Average Cost per Crash |
|---|---|---|---|
| **Jackknifes** | | | |
| **Other*:** ______________________ | | | |
| **Other*:** ______________________ | | | |
| **Other*:** ______________________ | | | |

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

# APPENDIX C: SUPPORTING DATA

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

**Table 38. Annual Number of PDO, Injury, and Fatal Rear-End Crashes with Pre-Crash Movement around a Curve, 2001–2005**

| Crash Type | 2001 | 2002 | 2003 | 2004 | 2005 | Average |
|---|---|---|---|---|---|---|
| Number of PDO Crashes | 28,765 | 27,705 | 29,520 | 26,168 | 26,245 | 27,681 |
| Number of Injury Crashes | 13,272 | 13,870 | 12,639 | 13,057 | 12,273 | 13,022 |
| Number of Fatal Crashes | 435 | 149 | 254 | 145 | 191 | 235 |

**Table 39. Annual Number of Injuries and Fatalities for Rear-End Crashes, 2001–2005**

| Crash Type | 2001 | 2002 | 2003 | 2004 | 2005 | Average |
|---|---|---|---|---|---|---|
| Injuries in Injury Crashes | 17,437 | 17,934 | 15,846 | 16,379 | 15,783 | 16,676 |
| Fatalities in Fatal Crashes | 445 | 153 | 259 | 145 | 201 | 241 |
| Injuries in Fatal Crashes | 348 | 125 | 451 | 187 | 226 | 267 |

**Table 40. Truck Driver Injuries and Fatalities in Rear-End Crashes, 2001–2005**

| Crash Statistic | 2001 | 2002 | 2003 | 2004 | 2005 | Average |
|---|---|---|---|---|---|---|
| Number Total Injury Crashes | 13,272 | 13,870 | 12,639 | 13,057 | 12,273 | 13,022 |
| Number Truck Driver Injuries | 1,662 | 1,286 | 1,511 | 1,421 | 1,828 | 1,542 |
| Number Drivers Injured per Injury Crash | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Number Total Fatality Crashes | 445 | 149 | 254 | 145 | 191 | 235 |
| Number Truck Driver Fatalities | 266 | 44 | 24 | 36 | 72 | 88 |
| Number Drivers Killed per Fatality Crash | 0.6 | 0.3 | 0.1 | 0.2 | 0.4 | 0.4 |

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

Part 1: Interview Guide begins on the next page.

Part 2: Survey Respondent Demographics follows.

**PART 1: INTERVIEW GUIDE**

ATRI is currently working on a trucking industry research initiative to develop a comprehensive cost-benefit analysis of select safety technologies, including rollover stability control, forward-looking collision warning systems, 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 SAFETEA-LU (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 E: ACKNOWLEDGMENTS

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