UMTRI 2009-22

Tracking the Use of Onboard Safety Technologies Across the Truck Fleet

Bruce M. Belzowski
Daniel Blower
John Woodrooffe
Paul E. Green

Prepared for:
Federal Motor Carrier Safety Administration

DTMC75-07-C-00004

March, 2009

Transportation Safety Analysis Division
Automotive Analysis Division
University of Michigan Transportation Research Institute
2901 Baxter Road
Ann Arbor Michigan 48109-2150

Technical Report Documentation Page

1. Report No. UMTRI-2009-22	2. Government Accessio0n No.	3. Recipient's Catalog No.
4. Title and Subtitle Tracking the Use of Onboard Safety Technologies Across the Truck Fleet		5. Report Date March 2009 6. Performing Organization Code
7. Authors Bruce M. Belzowski, Daniel Blower, John Woodrooffe, Paul E. Green		8. Performing Organization Report No. UMTRI-2009-22
9. Performing Organization Name and Address Transportation Research Institute 2901 Baxter Road University of Michigan Ann Arbor, Michigan 48109-2150		10. Work Unit No. 11. Contract or Grant No. DTMC75-07-C-00004
12. Sponsoring Agency Name and Address Federal Motor Carrier Safety Administration U.S. Department of Transportation 1200 New Jersey Avenue SE Washington, D.C. 20590		13. Type of Report and Period Covered Special Report 14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

The Transportation Safety Analysis and the Automotive Analysis Divisons at the University of Michigan Transportation Research Institute (UMTRI) initiated the Onboard Safety Technologies project in 2007, supported by FMCSA, to collect detailed information about the penetration of onboard safety technologies in the trucking fleet and future use of these technologies. The five technologies examined included: lane departure warning (LDWS), electronic stability control (ESC), forward and side collision warning (FCWS/SCWS), and vehicle tracking systems (TRACKING).

Previous work in estimating the penetration of onboard safety technologies never approached the question of technology penetration by sampling the popluation of trucking companies. This project uses that approach through the use of a random sample survey of the entire fleet of trucking companies to measure current penetration, future use, and the advantages available to companies employing these technologies. The source for the sample was the 2007 Motor Carrier Management Information System (MCMIS) file. Interviews were also conducted with companies with high penetration of the technologies as well as system suppliers of the technologies, in order to gather more detailed information about usage and future technology direction.

The results of the survey show the expected low levels of usage of LDWS, FCWS, and SCWS, slightly higher levels of usage of ESC, and much higher usage of TRACKING. Analysis shows higher usage related to larger company size. Company usage of these technologies is expected to double over the next five years.

The main factors noted by participants for using the technologies that vary little among the technologies include: proven safety benefits of the technologies, positive feedback by drivers, driver improvement, improved safety culture, reduced cost of accidents, and insurance benefits. The interviews yielded important views about the cost advantages of usage, the difficulty of justifying the purchase of the technologies, alternatives to safety technologies, and the future of technology integration.

17. Key Words	18. Distribution Statement
Onboard saftey technologies, lane departure warning system, electronic stability control, roll stability control, forward collision warning system, side collision warning system, vehicle tracking system.	Unlimited

19. Security Classification (of this report)	20. Security Classification (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	53	

Table of Contents

Tracking the Use of Onboard Safety Technologies Across the Truck Fleet

Executive Summary

This study by the University of Michigan Transportation Research Institute with funding from the Federal Motor Carrier Safety Administration (FMCSA) provides the first attempt to measure the penetration of these technologies throughout the entire truck fleet as well as trying to understand the opportunities and challenges managers face as they decide whether to introduce the technologies.

This study focused on six technologies: lane departure warning systems (LDWS), electronic stability control (ESC), forward collision warning systems (FCWS), side collision warning systems (SCWS), automatic cruise control (ACC) and vehicle tracking systems (TRACKING). Using a stratified random sample survey of the entire truck fleet, the study provides estimates of current and future usage of each technology.

The analysis of the survey produced the following key findings:

1. Companies are much less familiar with onboard safety technologies than expected.

The results of the survey indicate that carriers have low levels of familiarity with all of the technologies examined in this study. The larger the company, the more familiar the carriers are with the technologies. Of the technologies, carriers are most familiar with tracking systems and the level of familiarity increases with the size of the company fleet.

2. Penetration of onboard safety technologies, except for Vehicle Tracking Systems, is low compared to the number of companies that could be using them.

Current penetration for LDWS is approximately 4 percent, 8 percent for ESC, 3 percent for FCWS, 2 percent for SCWS, and 9 percent for Tracking Systems. When looking at the technology five year forecast of penetration rates across the different sized companies, it is anticipated that there will be significant increases in penetration rates with the largest companies. Tracking systems are expected to have an overall penetration of about 25 percent in 5 years while the remaining technologies are expected to achieve only about a 10 percent penetration.

3. Companies committed to LDWS, ESC/RSC, FCWS, or SCWS report significant safety improvements.

Positive feedback from drivers, driver improvement, and proven safety benefits are the main reasons for initiating using each of the technologies. While all technologies were reported as providing benefits, companies using the technologies, report an average of about a 20 percent

reduction in crashes and cost of crashes. It was found that companies reporting lower technology penetration tend to report much lower percentages of crash/crash cost reductions, while companies with higher penetrations in their fleets tend to report higher percentages of crash/crash cost reductions.

4. Companies report that Vehicle Tracking Systems offer both safety and business benefits.

Vehicle tracking systems, the most prevalent system in the U.S. fleet, offer carriers both safety and business value. Vehicle tracking systems offer safety benefits that may be linked to the influence of driver and vehicle monitoring. Technologies such as tracking systems provide a database of irregular driving events on each truck, which managers mine for monitoring and training purposes.

5. Carriers report significant challenges in introducing onboard safety technologies into their fleets.

The return on investment is a key motivator for adoption of safety technologies. Of all respondents 68 percent selected a favorable return on investment period to be 13 – 24 months.

The low levels of penetration of onboard safety technologies offer opportunities for system suppliers, though carriers, in general, are not familiar with how they work. If both the government and the system suppliers are interested in expanding the use of these technologies, they will need to expand their marketing and education efforts. These efforts will need to be focused on not only the larger carriers that have the most trucks, but also the smaller carriers that make up the bulk of the carriers in the U.S.

Besides the need for an increased understanding of these technologies, companies must also be able to see the value proposition the technologies provide. For all the companies in the study, the higher the penetration of a technology in their fleet, the more value they report receiving from that technology.

6. System integration, data monitoring and new products may fuel future deployment of onboard safety technologies

The future of onboard safety technologies may be in the integration of the various systems rather than in their individual use, though the integration process is in its early stages of development. The future of some of the technologies may also be affected by government mandates or incentives. But the longer the government waits to act, especially on incentives, the longer companies may wait to introduce the technologies into their fleets.

Introduction

The introduction of onboard safety technologies into the heavy truck fleet offers the potential of reducing the number of accidents, thereby making highways safer. The challenge is how to introduce these technologies into the heavy truck fleet and measure the penetration of these technologies in the fleet. This study by the University of Michigan Transportation Research Institute with funding from the Federal Motor Carrier Safety Administration (FMCSA) provides the first attempt to measure the penetration of these technologies throughout the entire fleet as well as trying to understand the opportunities and challenges managers face as they decide whether to introduce the technologies.

This study focused on six technologies: lane departure warning systems (LDWS), electronic stability control (ESC), forward collision warning systems (FCWS), side collision warning systems (SCWS), automatic cruise control (ACC) and vehicle tracking systems (TRACKING). Twenty years ago the study would not have asked about introducing these products because the technology needed to support them was either not available or was too immature to handle the tough conditions faced by heavy trucks. But today these technologies have matured to the point where their introduction has begun to take hold in the fleet population. This is based primarily on the advancements in electronics, computing power, and camera and radar technologies.

Previous research on implementing these technologies revealed the need to better understand the current penetration of these technologies across the heavy truck fleet, the issues carriers face when considering these technologies, particularly their cost and return on investment (ROI) time periods, and the technology development trajectory from the view of the system suppliers. (Houser et al., 2007) It is for this reason that FMCSA proposed this study to learn from the carriers themselves:

- Their familiarity with these technologies
- Their current and future use of these technologies across the entire trucking fleet
- Their reasons for implementing and the challenges they face when they implement these technologies.
- Some of the gains carriers are seeing from their use of the technologies.

Also, FMCSA wanted to hear from the system suppliers about introducing these technologies into the trucking fleet and their future development direction.

Since a census of the nearly 800,000 trucking companies in the US was not feasible, researchers prepared and administered a random sample survey of this population that provided the necessary information to answer the key questions of the study. The results for the survey were

supplemented with phone interviews with system suppliers and some users of the technologies, identified through the survey, to gather more detailed information about reasons for and challenges in implementing the technologies, and future implementation and development trends. Based on a review of the literature, this is the first random sample survey of the trucking company population that focuses on onboard safety technologies, and it offers a way of continuing to track the use of these technologies over time.

The General Population Survey

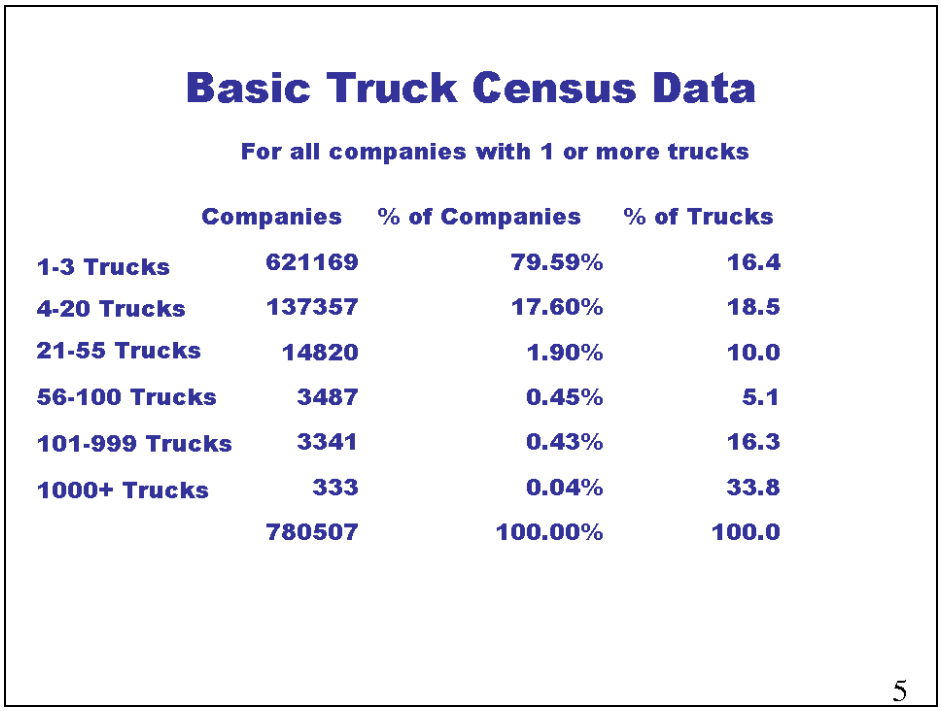
The execution of the general population survey of U.S. trucking companies demanded a well drawn sample that would allow weighting the responses back to the entire trucking population, and a survey process for contacting companies and gathering the necessary information.

The Survey Sample

Most business surveys suffer from not having a well defined population from which to draw a sample that would represent the total population. For example, there is no listing of all the automotive suppliers in the U.S. that could be used to draw a sample of companies. There is a tendency to focus on the larger companies and gather their opinions, understanding that they represent a subset of all suppliers. Fortunately for this study, there a census of all the trucking companies in the U.S. in the Motor Carrier Management Information System (MCMIS) carrier file. This file represents all companies that have Department of Transportation registration numbers, which is a requirement for all trucks and buses operated in interstate commerce, and for all vehicles transporting hazardous materials, regardless of whether interstate or intrastate. Since only interstate and hazmat carriers are required to register with the FMCSA, the MCMIS carrier file does not include all motor carriers. However, many states are beginning to require their intrastate carriers to register. Moreover, the file almost certainly includes the great majority of motor carriers, so it is a satisfactory sample frame for a survey of motor carriers.

What is interesting about the U.S. trucking population, as shown in Figure 1, is that the overwhelming number of companies that make up the trucking population have only one to three trucks in their fleets, and that less than 0.5 percent of all the companies own 50 percent of the trucks. Because of this skewed distribution of companies, a *stratified random sample* was used to help represent the population. The trucking company population was divided into six categories or strata, as shown in Figure 1, with each strata based on having a sufficient number of companies from which to draw a sample and the percent of trucks represented by each strata. This allows the survey to cover the full spectrum of truck operators. The intent was to combine the strata during analysis as strata were found that are similar to adjoining strata on key questions, but as will be seen, each strata, at times, responds differently from adjoining strata.

Figure 1: Basic Truck Census Data



Source; Motor Carrier Management Information System (MCMIS) carrier file

For this study, a total sample of 7,500 companies was drawn from the population of 780,507 companies that have one of more trucks in their fleets. The sample frame included all motor carriers with at least one truck in the fleet, and with a physical address in the United States. Sampling was done from the MCMIS carrier file as of April 11, 2007. Sampling was accomplished by means of an algorithm that randomized the order of the carriers within a strata and then drew the required number of carriers from each strata.

The original estimated response rate to the survey was expected to be approximately 30 percent, but as the survey progressed it became clear that the first sample would not generate the target number of cases. Accordingly, additional samples were drawn, ultimately totaling 7,500 cases, in order to produce the target number of cases in each strata. The distribution across strata is listed in Table 1. The Company Demographics for the companies in the survey sample are in Appendix B: Figures 23 to 29.

Table 1: Number of Companies in Sample by Strata

STRATA	NUMBER OF COMPANIES IN SAMPLE
Strata 1: 1-3 Trucks	**1500**
Strata 2: 4-20 Trucks	**1500**
Strata 3: 21-55 Trucks	**1500**
Strata 4: 56-100 Trucks	**1334**
Strata 5: 101-999 Trucks	**1333**
Strata 6: 1000+ Trucks	**333**
Total	**7500**

The Survey Process

In order to reduce the cost of data collection a web-based survey was designed that all of the survey respondents completed. This reduced the cost of performing long telephone interviews with potentially thousands of companies, or the cost of mailing, follow up, and data entry on thousands of respondents in a mail survey. The collection process involved sending emails to the approximately 27 percent of the MCMIS file that have an email address . The emails described the study and asked the respondent to complete the web survey by clicking on the link included in the email. The other 73 percent of the companies were contacted directly by telephone.

Telephone interviewers were trained to call the companies, find the right person to complete the survey (usually the owner, the safety director, or the head of operations), and gather his/her email address to send the link to the web survey. It was quickly found that many of the emails in the MCMIS files were incorrect and did not yield sufficient responses to the web survey, so the other 27 percent of the sample carriers were moved into the telephone interviewer queue.

Previous research on the penetration of onboard safety technologies suggested that many smaller companies would not use the technologies, so a short telephone survey was designed for Strata 1 and Strata 2 companies (20 or fewer trucks) that telephone interviewers used to ask about these companies' familiarity with the technologies, and their company's use of each technology. Telephone interviewers also used the short telephone survey for any respondent who reported that he/she did not want to give out an email address or expressed reluctance to participate in the

study.[1] Finding the right person to participate in the survey proved a challenging task, often necessitating multiple calls to the company in order to talk to the appropriate individual. Phone records show that telephone interviewers logged close to 20,000 calls to reach the 7,500 selected companies.

As part of the management of the survey, researchers tracked the disposition of all calls made to the sampled companies. Table 2 shows the results of calls based on various outcomes. The Non-Response category includes companies that were called up to four times without getting the respondent's email address or the completion of the short telephone survey; companies out of business, reporting no trucks, or no DOT number; companies with their phone number disconnected, out of service, or incorrect; a few companies that had not been contacted when data collection was discontinued; and companies that were contacted but did not respond to the survey. The 13 percent overall response rate reflects the difficulty of locating and surveying company owners, safety directors, or operations managers. But a subsequent survey would probably generate a better response rate because the companies will have received this report and would be more willing to participate. This study also provides a group of a thousand companies to use for potential follow up projects.

[1] Copies of the instruments used for the web survey and the short telephone survey are available upon request.

Table 2: Survey Statistics

STRATA	WEB SURVEY RESPONSES	PHONE SURVEY RESPONSES	TOTAL NUMBER OF RESPONSES
Strata 1: 1-3 Trucks	28	120	148
Strata 2: 4-20 Trucks	15	118	133
Strata 3: 21-55 Trucks	129	80	209
Strata 4: 56-100 Trucks	151	51	202
Strata 5: 101-999 Trucks	186	41	227
Strata 6: 1000+ Trucks	50	35	85
Total	559	445	1004

Table 2: Survey Statistics (continued)

STRATA	REFUSALS	NON-RESPONSE	NUMBER OF COMPANIES IN SAMPLE	RESPONSE RATE
Strata 1: 1-3 Trucks	168	1184	1500	10%
Strata 2: 4-20 Trucks	169	1198	1500	9%
Strata 3: 21-55 Trucks	230	1061	1500	14%
Strata 4: 56-100 Trucks	150	982	1334	15%
Strata 5: 101-999 Trucks	119	987	1333	17%
Strata 6: 1000+ Trucks	32	216	333	26%
Total	868	5628	7500	13%

The Weighting Process

The stratified random sample process allows an estimate of the penetration of onboard safety technologies for each strata, within a certain level of confidence. To generate national estimates from the survey responses, it is necessary to calculate case weights for each response and then use those case weights in analyzing the data. The case weights calculated account for the original selection probability of each case and also adjusts for non-response. Creating the weight variable used in the analyses is a multi-step process:

1. Create a sample weight for each strata (inverse of original selection probability):

   Total number of companies in each strata / Total number of companies sampled for each strata

2. Create the non-response rate adjustment for each strata:

   Total number of companies sampled / Number of responses

3. Create final weight variable with non-response rate adjustment for each strata:

   Non-response rate adjustment * sample weight

All the analyses in this report are based on the final weight variable calculated by this process.

The Carrier and System Supplier Interviews

To supplement the results of the survey, six carriers were interviewed that use some or all of the technologies under study and four system suppliers who develop and sell the technologies. The carriers who participated in the interviews tended to be CEOs, safety directors, or operations managers from companies of different sizes: one carrier has 4-20 trucks, one carrier has 21-55 trucks in its fleet, one carrier has 101 to 999 trucks in its fleet, and three carriers have 1000 or more trucks. System suppliers selling stability control systems, tracking systems, and forward and side collision warning systems are also represented.

The goal of the interviews with the carriers was to gather more detail about particular issues relating to onboard safety technologies such as when they began using the technologies, which ones they use, how satisfied they are with the reliability, safety results, cost savings, and maintenance needs, as well as their drivers' views about the technology. Carriers were also asked about their future plans for installing other technologies and possible incentives to install other technologies.

System supplier interviews were asked about the introduction of their products into the market and some of the marketing and development challenges they face. In terms of future products,

they were asked about their main areas for growth, what they thought the market would look like in 10 years, and the question of integrating safety technologies versus the development of separate technologies.

Major Findings

The major findings for the study focus on the main goals of the study: Familiarity with onboard safety technologies, penetration of technologies in the fleet, reasons for using the technologies, and future development. The rest of this report is organized according to the following major findings:

1. Companies are much less familiar with onboard safety technologies than expected.
2. Penetration of onboard safety technologies, except for Vehicle Tracking Systems, is low compared to the number of companies that could be using them.
3. Companies committed to LDWS, ESC/RSC, FCWS, or SCWS report significant safety improvements.
4. Companies report that Vehicle Tracking Systems offer both safety and business benefits.
5. Carriers report significant challenges in introducing onboard safety technologies into their fleets.
6. System integration and new products may fuel future developments in onboard safety technologies

1. Companies are much less familiar with onboard safety technologies than expected.

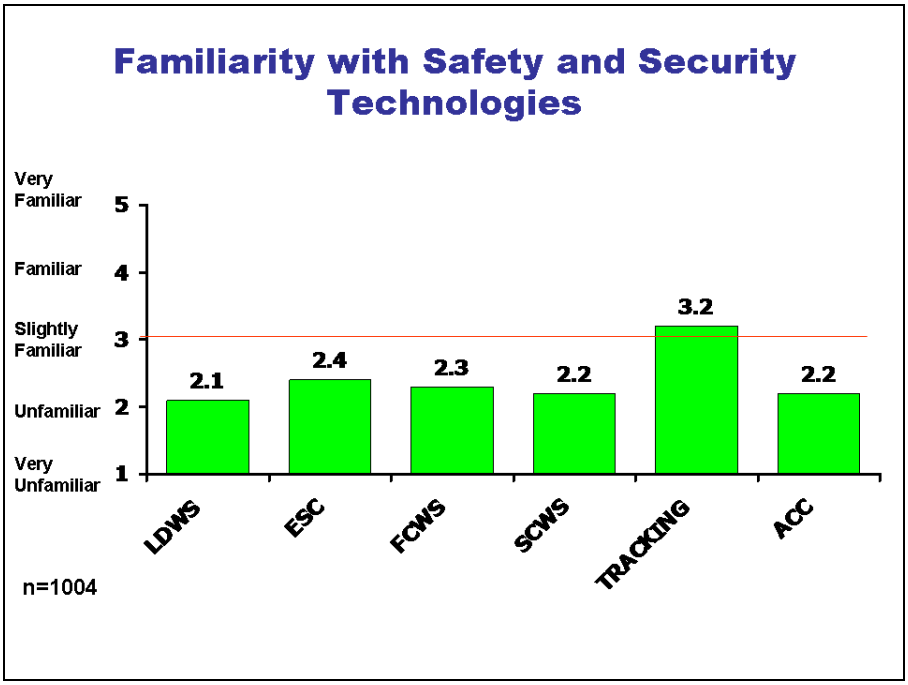
In the survey, all respondents were asked how familiar they are with what each of the technologies are supposed to do. Though they bring different levels of specificity to this question based on their experience, by having a large number of people respond to the question who, in theory, should be exposed to these technologies (CEOs, safety directors, or operations managers), high levels of familiarity were expected. But that was not the case.

Carriers report low levels of familiarity with the technology as seen in Figure 2[2]. The generally low levels of familiarity with these technologies speak volumes about the reasons for the low

[2] The notation n=1004 on the figure indicates that the results are based on 1,004 survey responses.

levels of penetration of these technologies in the trucking fleet. These are early days in the development and deployment of these technologies, and the lack of familiarity of these technologies is the leading indicator.

Figure 2: Familiarity with Safety and Security Technologies



The larger the company, the more familiar the carriers are with the technologies, but even the highest scores on the familiarity scale never reach the level of "familiar" for any strata. (See Appendix A, Figures 10 to 15) One exception in terms of technology familiarity is vehicle tracking systems. Companies, especially those with 56 or more trucks, are familiar with vehicle tracking systems. The higher levels of familiarity with vehicle tracking systems is the first in a number of ways tracking systems differ from the other technologies. Finally, an important point is that regardless of the precise meaning of the scale, the levels of familiarity are consistent across systems, with the exception of tracking systems.

Implications

- System suppliers and groups supporting the introduction of onboard safety technologies have a lot of work to do in order to make companies aware of the advantages these technologies offer.

- If the government is considering regulating the use of any of these technologies, there needs to be more effort put into raising the level of familiarity with them across the U.S. fleet. Regulating the use of technologies that companies are not familiar with them can cause a lot of resistance during implementation.

2. Penetration of onboard safety technologies, except for Vehicle Tracking Systems, is low compared to the number of companies that could be using them.

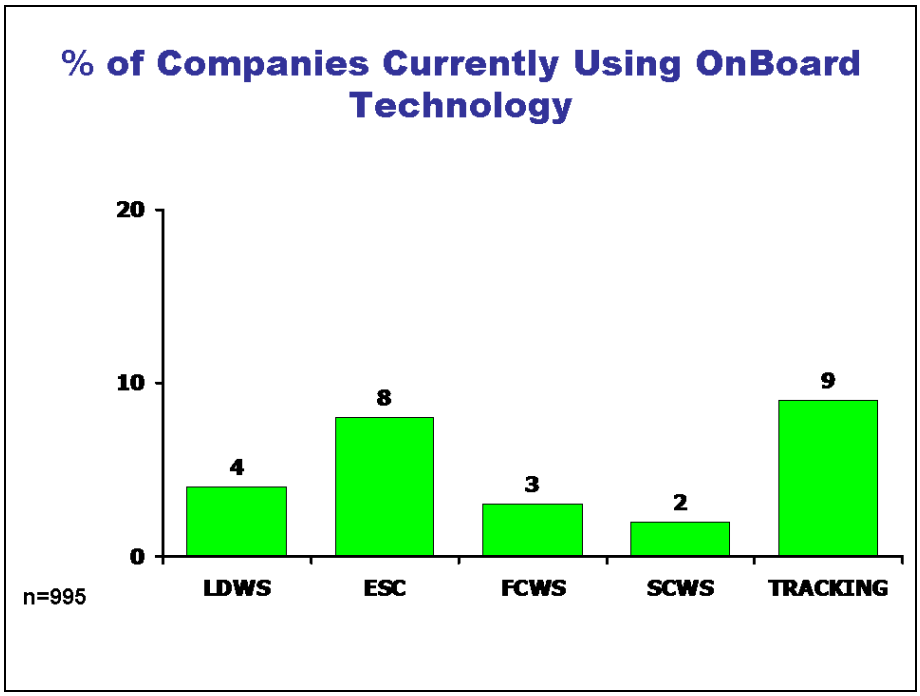
As the key question for the study, the issue of penetration across the fleet was examined from a variety of perspectives:

- The percent of companies in the U.S. fleet currently using each of the onboard safety technologies overall and by strata.
- For the companies using the technologies, the percent of their fleet currently using each of the technologies.
- The number of technologies used per company by strata.
- The reported percent of companies using each of the safety technologies in 5 years.
- For companies using the technologies, the percent of their fleet using each of the technologies in 5 years.

Across the entire population of truck operators, the use of onboard safety technologies is low as shown in Figure 3, which displays the estimated percentage of companies using the technologies. The low penetration of these technologies shows both the challenge and the opportunity for their deployment. The large number of companies not using these technologies offers the opportunity of considerable growth, while the challenge comes from trying to inform a large number of companies in the fleet of the value of deploying these technologies, especially the smaller companies with less than 100 trucks in their fleets.

Measuring the penetration of adaptive cruise control proved challenging because of the way adaptive cruise control is packaged. Adaptive cruise control tends to be sold as part of the forward collision warning system, but it can be separately disabled, while retaining FCWS capability. Respondents taking the phone interview were asked if they used adaptive cruise control in their fleet, and 12 percent of the 445 companies that participated in the phone interviews report they use the technology. This question was also asked on the web survey, but it was asked only in the context of companies that reported using forward collision warning systems, because these two technologies use the same sensors and are typically sold as a package. The response of the 28 respondents who said they used forward collision warning systems (3 percent of the web survey respondent population) was that 95 percent of their fleet used adaptive cruise control. It is unclear if the discrepancy between the phone interview and the web survey is related to the methodology or to the type of company that completed the phone interview and the web survey: smaller companies were targeted in the phone interview while the larger companies were targeted for the web survey.

Figure 3: Percent of Companies Currently Using Onboard Technologies



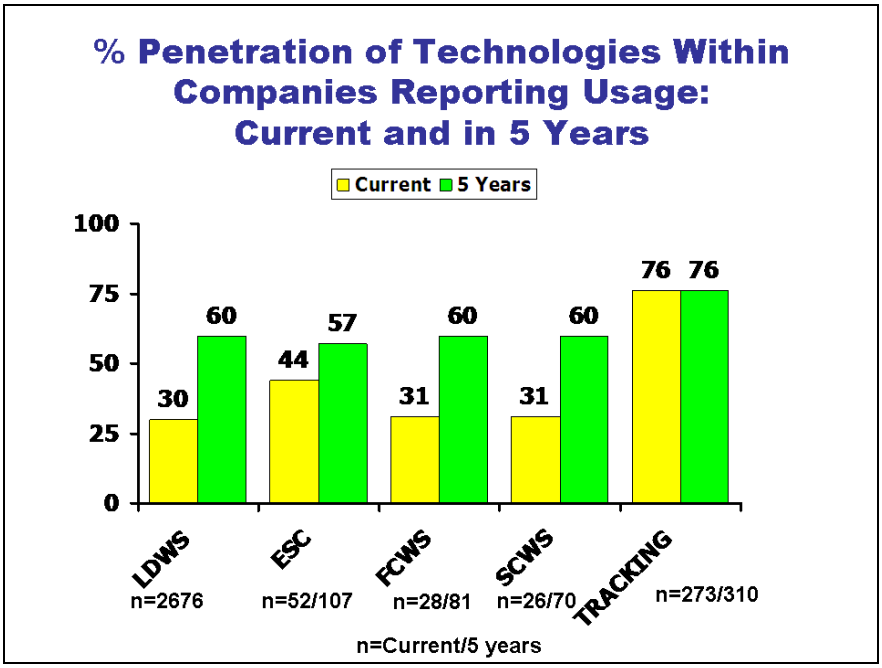
In Appendix A, Figures 16 to 20 show the penetration at the company level of each technology across the six strata. The largest strata with 1000 or more trucks per company is far and away where the most deployment occurs, though even in this strata the percent of penetration is low.

When looking across the strata, two technologies stand out as different from the others: stability control systems and vehicle tracking systems. Stability control systems tend to have the same penetration in the 1000 or more trucks strata as lane departure and forward and side collision warning systems, but stability control systems tend to have higher penetration in the strata of smaller companies. Vehicle tracking systems, though they only have a nine percent penetration rate overall, have penetration rates of nearly 50 percent or more for companies with 56 or more trucks. Even companies with 21 to 55 trucks have a 35 percent penetration of vehicle tracking systems.

Companies that report using these technologies were asked the percent of their truck fleet that was actually equipped with the technology. A variety of penetration rates was found within the companies for each technology, as shown in Figure 4. Within these fleets that are using the technologies, there is an average 30 percent penetration rate for lane departure warning systems, forward collision warning systems, and side collision warning systems; a 44 percent penetration rate for stability control systems; and 76 percent penetration rate for vehicle tracking systems. Note also that the fleets that report using the technologies also indicated that they would deploy

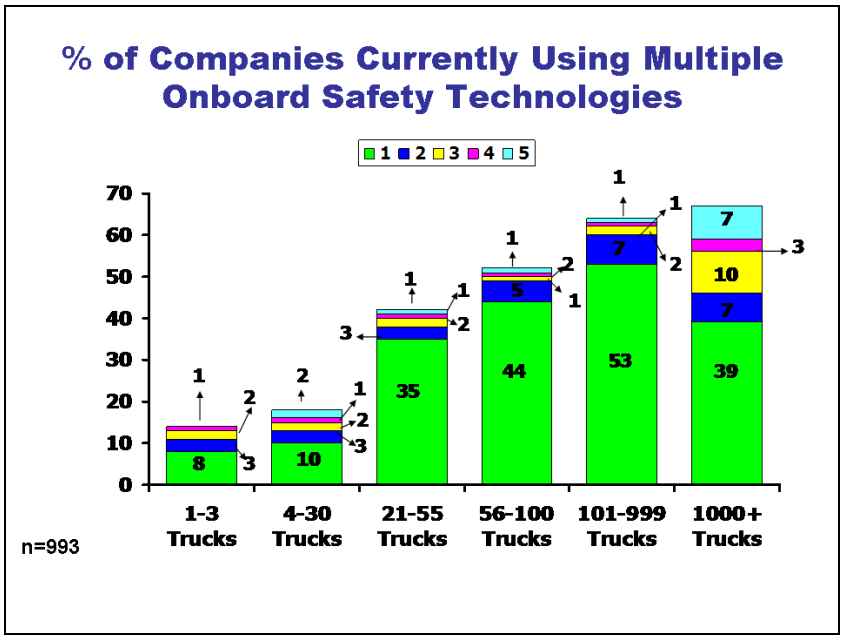
significantly more systems within the next five years, with the exception of vehicle tracking systems, which already have a high rate of deployment within the fleets.

Figure 4: Percent Penetration of Technologies Within Companies Reporting Usage



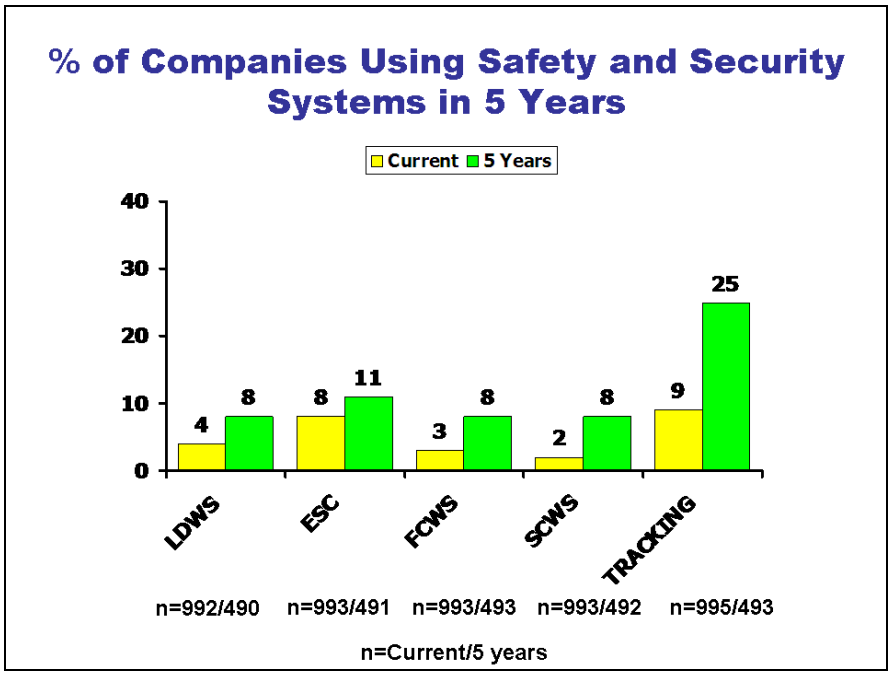
Another way of looking at a company's use of onboard safety technologies is to look at the number of different technologies deployed in its fleet. Some of the companies use multiple technologies, but most use only one, as shown in Figure 5, though the larger the company, the more technologies it uses.

Figure 5: Percent of Companies Currently Using Multiple Onboard Safety Technologies



Companies report the rate of penetration of onboard safety technologies will increase over the next 5 years, as shown in Figure 6, particularly for vehicle tracking systems. The increases in some of the other technologies will double or triple, but they will still barely reach 10 percent penetration. But when looking at the penetration rates across the different sized companies, there will be significant increases in penetration rates with the largest companies, as seen in Appendix A, Figures 16 to 20. In 5 years, significant increases in penetration rates are expected within companies for all technologies, except vehicle tracking systems, as shown in Figure 4.

Figure 6: Percent of Companies Using Safety and Security Systems in 5 Years



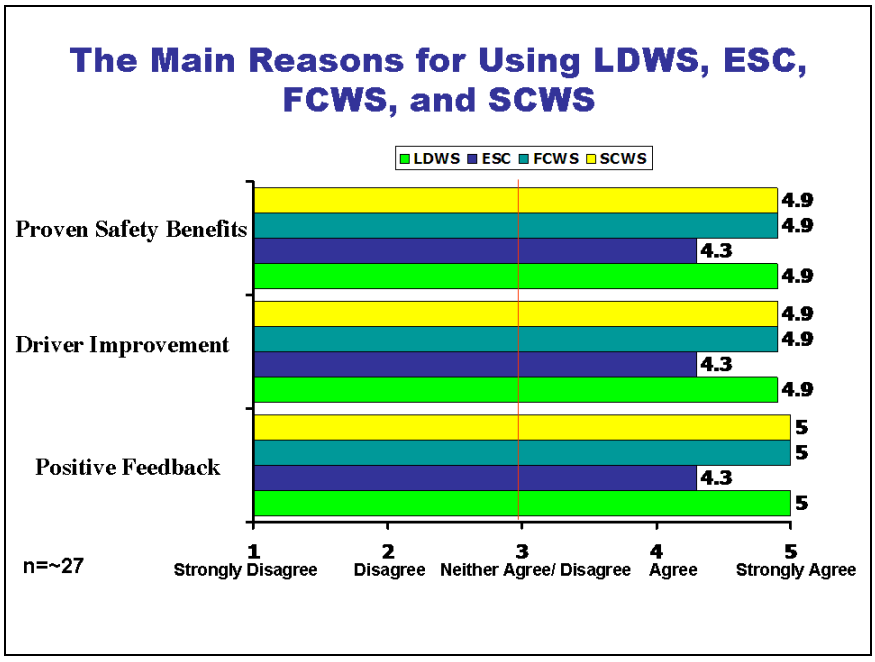
Implications

- Opportunities abound for growth in LDWS, ESC, FCWS, SCWS and Tracking Systems because of low penetration of the technologies.
- There is expected growth in each of the technologies over the next 5 years.
- Few companies use multiple technologies, making the sale of multiple technologies to companies more difficult. A more integrated approach of the technologies may provide the sale of multiple technologies.

3. Companies committed to LDWS, ESC/RSC, FCWS, or SCWS report significant safety improvements.

The companies that are using onboard safety technologies are convinced that the technologies provide benefits to their companies. From the survey of companies using the technologies, they report that they agree that positive feedback from drivers, driver improvement, and proven safety benefits are the main reasons for initiating using each of the technologies, as shown in Figure 7. Some other reasons companies report include an improved safety culture, cost of accidents, and insurance benefits (Appendix A: Figures 21 to 22) Respondents do not report that issues such as improved their safety rating, financial incentives from shippers or carriers, or required by shippers are main reasons for initiating the use of these technologies.

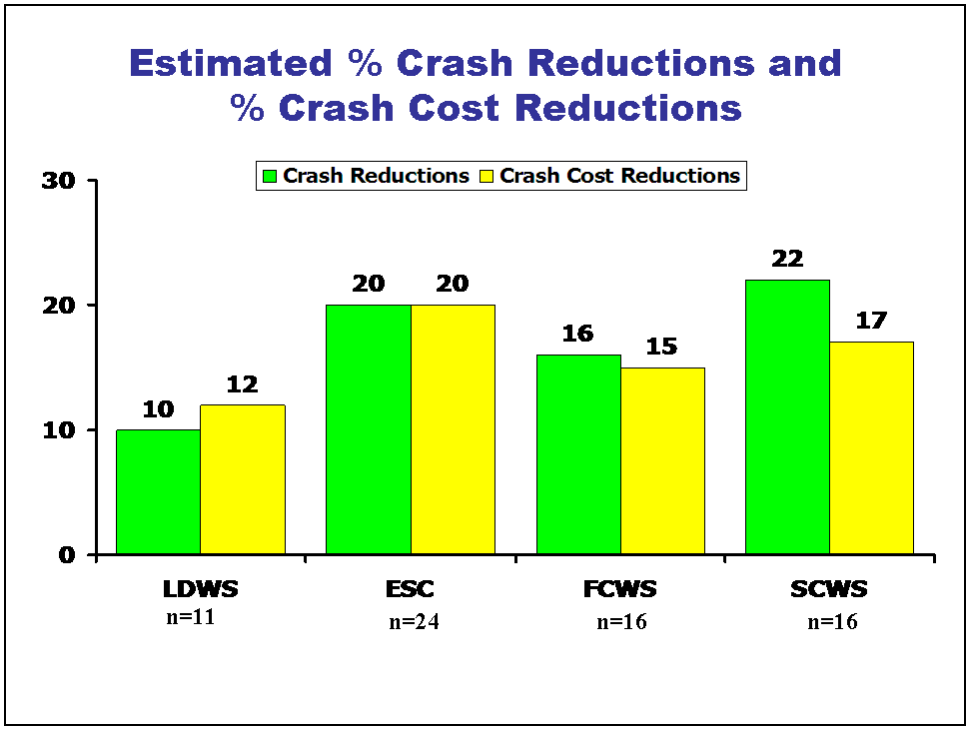
Figure 7: The Main Reasons for Using LDWS, LDWS, ESC, FCWS, and SCWS



Though only about a third of the companies that are using the technologies report their gains in crash reductions and cost of crash reductions, as Figure 8 shows, they are averaging about a reported 20 percent reduction in crashes and cost of crashes. (Note that the survey did not request data to validate the reported reductions.)These companies are probably reporting what they see as their actual reduction in crashes over time, but they may also be underreporting the gains from these technologies because they cannot verify how many crashes are avoided because of the technologies. The technologies provide a database of irregular driving events on each truck, which managers mine for monitoring and training purposes, so managers have some sense

of how the technologies may have helped avoid crashes. But drivers, in general, will not report all the instances where the technologies kept them from crashing for fear of being labeled as a driving risk.

Figure 8: Estimated Percent of Crash Reductions and Crash Cost Reductions



Though carriers report on average a significant percentage of improvements in crash and crash cost reductions, they seem to be divided into those who see some or a lot of improvement and those who see no improvement. The distributions in Table 3 show this split.

Table 3: Reduction of Crashes and Crash Cost by Companies Reporting Positive Reduction and No Change

ANALYSIS	COMPANIES REPORTING…			
	No change		Positive reduction	
	Number of companies	% reduction	Number of companies	% reduction
LDWS Crash reductions	5	0	6	26
LDWS Crash Cost Reductions	5	0	5	32
ESC Crash Reductions	7	0	17	20
ESC Crash Cost Reductions	7	0	15	20
FCWS Crash Reductions	8	0	8	32
FCWS Crash Cost Reductions	7	0	5	33
SCWS Crash Reductions	6	0	10	40
SCWS Crash Cost Reductions	5	0	7	34

One possible explanation for the dichotomy shown in Table 3 is that some companies have not fully committed to the technologies. Companies with lower penetrations of these technologies tend to report much lower percentages of crash/crash cost reductions, while companies with higher penetrations in their fleets tend to report higher percentages of crash/crash cost reductions. Table 4 below shows the generally high correlations among these variables. These analyses, though not conclusive, mean that companies need to make a significant commitment to the technologies in order to see the desired results.

Table 4: Correlations of Crash and Crash Cost Reductions by the Penetration of Each Technology

ANALYSIS	CORRELATION
% Penetration of LDWS by % Crash Reductions*	.73
% Penetration of LDWS by % Crash Cost Reductions	.60
% Penetration of ESC by % Crash Reductions*	.47
% Penetration of ESC by % Crash Cost Reductions	.53
% Penetration of FCWS by % Crash Reductions*	.43
% Penetration of FCWS by % Crash Cost Reductions	.29
% Penetration of SCWS by % Crash Reductions*	.45
% Penetration of SCWS by % Crash Cost Reductions	.17

* The % Crash Reductions and % Crash Cost Reductions used for each analysis are those reductions attributed to each of the technologies, e.g. the % Penetration of LDWS is correlated with the % Crash Reductions attributed to the use of LDWS.

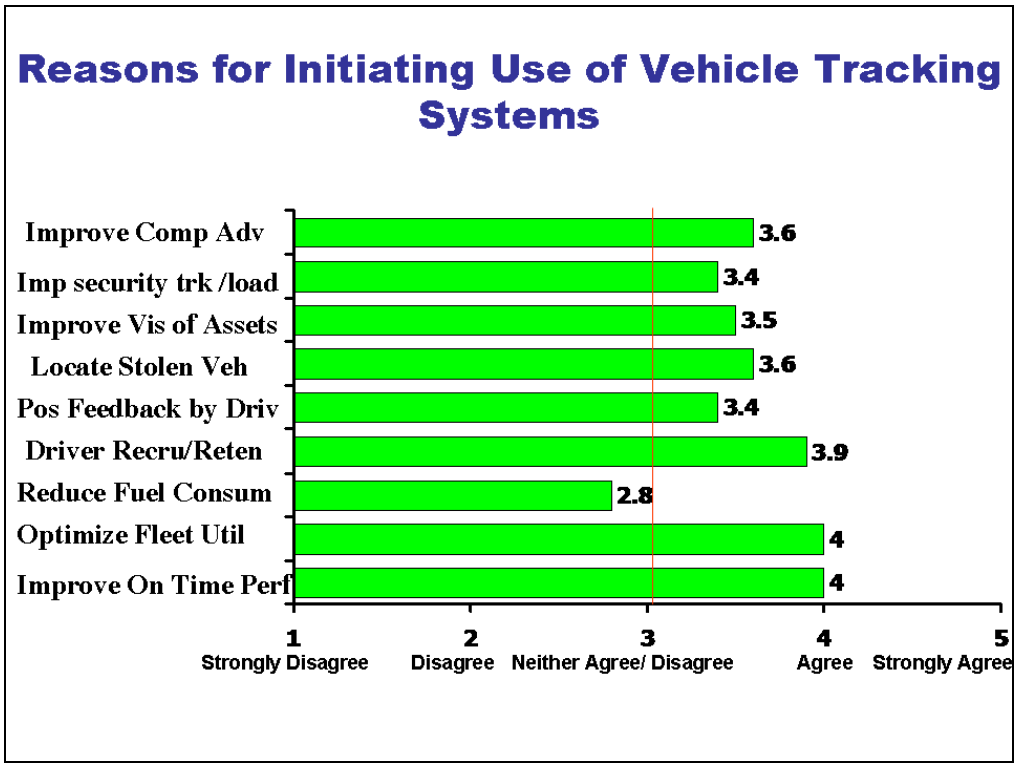
Implications

- Companies using onboard safety technologies in higher percentages in their fleets tend to reap rewards, both monetary and from their drivers
- Companies committed to onboard safety technologies may have a more trusting relationship with their drivers and possibly a safer fleet than those who do not commit to the technologies.

4. Companies report that Vehicle Tracking Systems offer both safety and business benefits

In the survey, the reasons for using vehicle tracking systems were measured in two ways: through a closed ended question and through an open ended question. The closed ended question focused only on the business aspects and theft reduction provided by vehicle tracking systems as shown in Figure 9. Carriers agree that the three main reasons for initiating use of vehicle tracking systems include: improving on time performance, optimizing fleet utilization, and driver recruitment and retention. The other reasons where they share some agreement on reasons to initiate use include: locating stolen vehicles, improving their competitive advantage, improving the visibility of their assets, and improving the security of their trucks and their loads. Companies do not agree that reducing fuel consumption is a main reason for using tracking systems.

Figure 9: Reasons for Initiating Use of Vehicle Tracking Systems



The open ended question asked about things that needed to be known about tracking systems in order to better understand their value to their company. This question elicited a similar set

of responses, as seen in Table 5, including issues surrounding improving and optimizing the utilization of the fleet and customer demand and service.

Table 5: Advantages of Using Vehicle Tracking Systems

RESPONSES (n=62)	PERCENTAGE
Driver support and accountability	**19%**
Customer demand or customer service	**15%**
Safety improvements and tracking	**13%**
Logistic analysis and routing	**13%**
Ease of travel and delivery	**10%**
Reduced communication cost	**10%**
Others include: **Fuel savings** **Insurance support for litigation** **Fuel tax reporting** **Reduced labor cost**	**20%**

Safety improvements appeared in this list as one of the main things that needed to be understood about companies' use of tracking systems. Safety improvements related to tracking systems were identified by some of the carrier interviewees, who noted that there are a number of ways of using tracking systems to support driver/safety improvements including downloading a driver's event logs that note speeding, time driven, hard braking, and major engine deceleration. One carrier related a story of the accident support and connectivity with the driver available through tracking systems that saved his fleet millions of dollars:

> "I have a direct link to all my vehicles through our tracking system. It provides me with an instant update of any accident that one of our driver's is involved in. One night I received a notice of a fatal accident, and I was able to talk to our driver immediately. It turned out that witnesses claimed that our driver was speeding, but the tracking system saves critical event information and proved that our driver was not speeding. This incident

> alone saved us millions of dollars and paid for the complete installation of tracking systems in our fleet."

Another carrier interviewee notes that its tracking system has not reduced accidents, but it has reduced the number of speeding tickets. Survey respondents also report a 3 percent reduction in vehicle and trailer theft and an 11 percent increase in business opportunities, though almost 90 percent of the respondents report little or no theft reductions or less than half of respondents report increases in business opportunities.

Implications

- Vehicle tracking systems offer safety benefits that are not commonly understood.
- Monitoring driver behavior through tracking systems is one of the ways of showing some of the potential benefits of safety systems. When drivers do not want to report an error, the tracking system may provide important support for the systems.
- These systems may provide important support for insurance/accident reconstruction.

5. Carriers report significant challenges in introducing onboard safety technologies into their fleets.

Companies considering introducing onboard safety technologies into their fleets go through a complex analysis that includes a variety of factors. In particular, they consider which of the technologies to introduce, the return on investment (ROI) of each technology, and the role the technologies will play in driver improvement. All of these factors may interact when deciding to introduce new technologies into the fleet, and it may come down to which problem a company is trying to solve. For example, the reason for deciding which technology to introduce may be a combination of reducing accidents or continuously improving driver performance or both.

Return on investment was a topic discussed in all of the carrier and system supplier interviews. Survey respondents report, as shown in Table 6, that they expect an ROI within 13 to 24 months, though some carriers are willing to wait more than 36 months. Carriers see these technologies as primarily safety technologies, though tracking systems offer both safety and business opportunities, so they expect a reduction in accidents, the cost of accidents, or general driver improvement to justify the introduction of a technology. There are a two important points that can confound or delay these results:

- Heavy truck accidents, in general, are rare events. In 2007 there were 2.02 fatalities, 33 non-fatal injury crashes, and 147 property damage only accidents per 100 million miles driven. (2007 Traffic Safety Facts) A large fleet has a better chance of driving 100 million miles in a shorter period of time, but a smaller fleet will take longer to reach that mark, thus making it seem like the technologies are not providing a payback.

- Savings from accidents avoided and prevented by the technologies are not always reported by drivers, so estimates of driver improvement may underestimate the value of the technologies.

Carriers report that the introduction of these technologies was a pro-active approach by management to develop a culture of safety in the company, and in order to measure the ROI for the technologies some companies use a rigorous testing protocol with a good sample size and control and pilot groups.

Table 6: Acceptable Return on Investment Payback Period

RETURN ON INVESTMENT PAYBACK PERIOD (n=46)	PERCENTAGE
Less than 12 months	1%
13-24 months	68%
25-36 months	1%
>36 months	30%

Besides ROI, other issues challenge the introduction of onboard safety technologies such as driver resistance, reaching the smaller carriers that make up over three quarters of the carrier population, though less than 40 percent of the trucks, the way safety technologies are offered at the manufacturer level, and the role of government in supporting the introduction of these technologies. Safety managers tend to support the introduction of these technologies as a way of improving and monitoring driver behavior. Some interviewees note that older drivers tend to dislike the technologies, while younger drivers like them. A few of the interviewees spoke about an upcoming shortage of drivers, once the economy recovers, and that onboard technologies can provide support for inexperienced drivers.

Smaller fleets provide a challenge for system suppliers as they sell them onboard safety technologies because there are so many of them, and because they tend to rely on internal training and monitoring via tracking systems to substitute for the other safety technologies. The carrier interviews with smaller companies provide insight into how companies try to develop and maintain a safety culture without purchasing onboard safety technologies. They tend to focus more on in-depth hiring practices and also on frequent safety meetings to review driver records recovered from tracking systems. One carrier also has developed a novel reinforcement process:

> "We see our incentives as a family affair. We reward our drivers who are accident-free during the month with a certain number of cents per mile incentive. We've found that reminders from their wives, if they don't come home with the incentive, is very helpful. In my past job, we used the opposite approach where we dismissed drivers if they accumulated a certain number of points because of accidents. Here I start the new drivers off at lower number of cents per mile and increase that after 6 months if they are accident-free. So, we're providing drivers performance pay based on safety. We've had virtually no turnover and the average number of years with the company is 9 years, which is very high for this industry."

The way safety technologies are offered from the truck manufacturer can be an impediment or a boon for the introduction of safety technologies. A couple of interviewees note the difference between the ways trucks are ordered in the U.S. versus the European Union (E.U.). In the E.U., the manufacturers and suppliers set specifications for new trucks; whereas, in the U.S. the attitude is that the fleets know what is best for their business. Consequently, fleets can specify which technologies are installed by the manufacturer. System suppliers report that this system slows the introduction of safety technologies as the technology must move from its status as an option to a standard feature on a truck.

One way a technology moves from an option to a standard feature on a new truck is through government regulation. System suppliers report that government mandates help reduce the cost of introducing technology by increasing volume. But one of the key issues now being considered by the government is the use of incentives to increase penetration of these technologies. System suppliers note the Catch-22 situation that occurs when the longer the government takes to make a decision about incentives, the less incentive carriers have to purchase the technologies. Carriers say, "Why should I spend the money now, when I can wait until the incentives arrive?"

Finally, one of the system supplier interviewees described one of the most common reasons for a company to introduce onboard safety technologies: a driver for the company is involved in a fatal accident. As the supplier states, "The settlement and court costs of one accident can cover the cost of installing our technology."

Problems with onboard safety technologies

In the survey, carriers were asked what problems they had with the installation and use of each of the safety technologies or problems with the specific system itself. For LDWS, the main problems reported were false alarms, the loud alarms that wake up one of the tandem drivers

who is sleeping, snow-covered highways that keep the system from reading the lane markers, frequent repairs, and installation challenges.

For FCWS, the main problems reported were false alarms from readings of fixed objects and downloading data from the system that is used to track driver behavior. For SCWS, the main problems include side sensors that are prone to damage. No problems were reported for ESC.

Because vehicle tracking systems have been used in the industry longer than any of the other technologies, there are more units in use and consequently more problems reported by the carriers in the survey. As seen in Table 7, there is a plethora of problems carriers report about their vehicle tracking systems. Issues relating to driver resistance and tampering with the tracking systems range from drivers feeling that "Big Brother" is watching them to actually disconnecting and disabling the tracking systems. Several carriers report that the systems are easily disabled, implying they would like it if the systems were tamper-proof. A few responses note how drivers did acclimate to the system over time (from a few weeks to a few months to a few years), while another notes that drivers initially use the system but "use drops substantially unless you have an automated, systemic reporting suite that creates exception reporting without manual intervention."

Table 7: Problems with Vehicle Tracking Systems

VEHICLE TRACKING PROBLEMS (n=110)	PERCENTAGE
None	15%
Driver resistance/tampering	30%
Unreliable connectivity	26%
Durability	24%
Training issues	3%
Cost of units	2%
Units lost to owner-operators	2%
Other	5%

Though drivers may disable the systems, the connectivity of the systems themselves is reported as unreliable in a number of instances including inner cities, rural areas, and areas with military bases, but carriers also report occasional "dead spots" and a lack of connectivity and integration between the tractor and the dispatch system. Some carriers report that their tracking system is not a "real time" system, so "it will show a driver at one point and a minute later show him 75 miles away."

Durability of the unit itself is also a common problem reported by the carriers. Battery life is mentioned frequently as a problem as well as issues relating to temperature, vibration, and system placement on the tractor. These hardware failures seem more of a durability issue, and the maintenance and servicing of these failures also is noted as a problem with a lack of service centers available throughout the U.S.

Finally, it is interesting that carriers do not report the cost of the units and training on the technology as problems as often as other issues, though they report a problem getting their tracking units back from owner-operators after they leave the employ of the carrier.

The high number of problems related to tracking systems could be a result of a variety of factors. It may be that tracking systems have a more complicated task in connecting to dispatch systems throughout the country while LDWS, ESC, FCWS, and SCWS have very focused tasks on the vehicle. Or it may be that the dual role of safety and business support of tracking systems lends itself to higher expectations in carriers.

Implications

- There are significant opportunities for growth in onboard safety technologies, but companies must be provided with a strong case for ROI.
- Considering the frequency of these responses concerning tampering and driver resistance, system suppliers that can provide tamper-proof systems could have an advantage in the marketplace.
- Companies that can provide a clear business rationale for using tracking systems and consequences for drivers tampering with them will be more successful in using them despite any other problems inherent in the technology.
- Companies using the technologies report important increases in safety benefits. But because accidents are rare events, testing the technologies for a short period of time may not show a safety savings.
- Companies that compensate for not using onboard safety technologies through training and better hiring practices need data that proves the case for installing these technologies.

6. System integration and new products may fuel future developments in onboard safety technologies

Technology Integration

System supplier interviewees were asked about the future direction of onboard safety technologies. Though the number of system supplier interviewees was small, two main areas about the future emerged: the integration of technologies and future products. The integration of onboard safety technologies faces a number of challenges. First, each of the technologies has its own unique sensors, except for FCWS and ACC which are usually sold in combination. In the future, sensors will provide information to multiple systems with the overall system deciding which of the warnings takes priority. But from the business side of the issue, system suppliers spend significant sums of money researching the market and developing their systems and may be unwilling to give up their proprietary technology or their potential profit. Finding a way of overcoming this issue will go a long way towards integration of safety technologies.

Another integration issue comes from the current specification truck ordering system that allows fleets to decide which technologies to put onto their new trucks. In this current system, it is difficult to combine technologies, but one system supplier suggests that the manufacturer may put in the technologies separately, and then do the work of integrating them. Standardized interfaces and sensors can also help this process along, providing more of a "plug and play" environment.

Finally, the issue of integration is being investigated by the U.S. government through the Integrated Vehicle-Based Safety Systems initiative (IVBSS). Researchers are looking at the interoperability, human factors, and system development issues surrounding this safety technology integration project. One system supplier questioned how the technologies can be integrated given their proprietary nature.

Future Products

System suppliers also provide some insight into the technologies and issues that will be affecting safety systems in the near future. On the technology side, the system suppliers think there will be a move to more cameras on the vehicle (side mounted cameras for cornering) and in the vehicles (cameras in the cab). Though they predict a positive response for cameras in the cab in terms of accident prevention, they expect a very negative response by drivers. The main issue that cameras in the cab address is driver fatigue. Dealing with driver fatigue continues to be one of the most challenging issues facing carriers, but it is unclear if cameras in the cab will help overcome this challenge. Will companies monitor drivers remotely in real time or will the cameras record actions in the cabin for accident reconstruction? The main goal is to keep drivers from driving when fatigued rather than disciplining them after the fact.

Finally, one system supplier reports that there are efforts to model the behavior of drivers in order to predict when and where driving problems occur from a geographic standpoint, situational standpoint, and driver characteristics.

Implications

- Because of the potential growth in the use of onboard safety systems, the integration of these technologies offers economies of scale if system suppliers can be part of the integration process.
- The introduction of cameras into the cabin will most likely be met with resistance by drivers unless companies can drivers the value the systems will provide them.

Conclusion

The analysis of the survey produced the following key findings:

The results of the survey indicate that carriers have low levels of familiarity with all of the technologies examined in this study. The larger the company, the more familiar the carriers are with the technologies. Of the technologies, carriers are most familiar with tracking systems and the level of familiarity increases with the size of the company fleet.

Current penetration for LDWS is approximately 4 percent, 8 percent for ESC, 3 percent for FCWS, 2 percent for SCWS, and 9 percent for Tracking Systems. When looking at the technology five year forecast of penetration rates across the different sized companies, it is anticipated that there will be significant increases in penetration rates with the largest companies. Tracking systems are expected to have an overall penetration of about 25 percent in 5 years while the remaining technologies are expected to achieve only about a 10 percent penetration.

Positive feedback from drivers, driver improvement, and proven safety benefits are the main reasons for initiating using each of the technologies. While all technologies were reported as providing benefits, companies using the technologies, report an average of about a 20 percent reduction in crashes and cost of crashes. It was found that companies reporting lower technology penetration tend to report much lower percentages of crash/crash cost reductions, while companies with higher penetrations in their fleets tend to report higher percentages of crash/crash cost reductions.

Vehicle tracking systems offer safety benefits that may be linked to the influence of driver and vehicle monitoring. Survey respondents report a 3 percent reduction in vehicle and trailer theft and 11 percent increase in business opportunities, though almost 90 percent of the respondents report little or no theft reductions or less than half of respondents report increases in business

opportunities. Technologies such as tracking systems provide a database of irregular driving events on each truck, which managers mine for monitoring and training purposes.

For forward collision warning, the main problems reported were false alarms from readings of fixed objects and downloading data from the system. For side collision warning systems, the main problems include side sensors that are prone to damage. No problems were reported for electronic stability control.

Few companies use multiple technologies, making the sale of multiple technologies to companies more difficult. A more integrated approach of the technologies may promote the sale of multiple technologies. The integration of these technologies offers economies of scale if system suppliers can be part of the integration process. However the degree of integration depends on the commonalities of sensors, processing hardware, vehicle system hardware and in cab warning systems. For example FCWS uses radar, LDWS uses cameras, and ESC uses inertial sensors, none of which are duplicative.

The return on investment is a key motivator for adoption of safety technologies. Of all respondents 68 percent selected a favorable return on investment period to be 13 – 24 months.

The low levels of penetration of onboard safety technologies offer opportunities for system suppliers, though carriers, in general, are not familiar with how they work. If both the government and the system suppliers are interested in expanding the use of these technologies, they will need to expand their marketing and education efforts. These efforts will need to be focused on not only the larger carriers that have the most trucks, but also the smaller carriers that make up the bulk of the carriers in the U.S.

Besides the need for an increased understanding of these technologies, companies must also be able to see the value proposition the technologies provide. Companies using the technologies report strong agreement with the positive effects the technologies provide for their drivers and the overall safety benefits for their companies. But it is primarily the larger carriers that use the technologies today. The more miles companies drive, the easier it is to see the value in terms of accident reduction and cost of accidents. Smaller carriers that drive fewer miles need to be aware that the payback period for the technology will occur over a longer period of time, on average, than for carriers that drive more miles. For all the companies in the study, the higher the penetration of a technology in their fleet, the more value they report receiving from that technology.

Vehicle tracking systems, the most prevalent system in the U.S. fleet, offer carriers both safety and business value. Tracking systems provide multiple benefits for companies, but these benefits are matched by a significant number of problems. Other safety technologies have fewer and more specific problems in installation and use.

Finally, the future of some of the technologies may be affected by government mandates or incentives. But the longer the government waits to act, especially on incentives, the longer companies may wait to introduce the technologies into their fleets. Also, the future of onboard safety technologies may be in the integration of the various systems rather than in their individual use, though the integration process is in its early stages of development. In the meantime, carriers have the opportunity to take advantage of these technologies and system suppliers have the opportunity to present their value proposition.

In summary:

1. Companies are much less familiar with onboard safety technologies than expected.

2. Penetration of onboard safety technologies, except for Vehicle Tracking Systems, is low compared to the number of companies that could be using them.

3. Companies committed to LDWS, ESC/RSC, FCWS, or SCWS report significant safety improvements.

4. Companies report that Vehicle Tracking Systems offer both safety and business benefits.

5. Carriers report significant challenges in introducing onboard safety technologies into their fleets.

6. System integration, data monitoring and new products may fuel future deployment of onboard safety technologies

References

Houser, Amy, Federal Motor Carrier Safety Administration (FMCSA), Murray, Dan, and Dick, Virginia American Transportation Research Institute (ATRI) *On-board Safety Technology Survey Synthesis* National Center for Statistics and Analysis. Department of Transportation. Washington D.C. FMCSA-MCRR-07-028

Traffic Safety Facts 2007. National Highway Traffic Safety Administration. National Center for Statistics and Analysis. Department of Transportation. Washington D.C. DOT HS 811 002.

The Authors

Bruce M. Belzowski is the associate director and an assistant research scientist, in the Automotive Analysis Division's Industry Structure Group. He has authored research reports focusing on a variety of automotive topics including product development, manufacturer-supplier-dealer relations, globalization, information technology, knowledge management, and human resources. His current research topics include Product Lifecycle Management (PLM), powertrain strategies,

and globalization of the automotive industry. He is co-director of UMTRI's China Automotive Program and Powertrain Strategies Program. He is also a steering committee member of the GERPISA global automotive research group in France and a Joint Researcher at the Institute for Technology, Enterprise, and Competitiveness at Doshisha University in Kyoto, Japan. He can be reached at bbl@umich.edu or 734-936-2704.

Daniel Blower is an Associate Research Scientist in the Transportation Safety Analysis Division at UMTRI and Director of the Center for National Truck and Bus Statistics. He has over 20 years of experience in research and data collection related to traffic safety. Areas of recent research include work to estimate the safety benefit of advanced collision avoidance technologies developed for trucks and for light vehicles, including roll stability, vehicle stability control, lane departure warning and prevention, and side object detection. A related primary research interest is traffic crash causation. Dr. Blower helped to develop the methodology and served as a consultant to the Large Truck Crash Causation Study (LTCCS) and to the Bus Crash Causation Study for the Federal Motor Carrier Safety Administration. He recently completed a research using LTCCS data to examine the contribution of vehicle mechanical condition to crash risk. He can be reached at dfblower@umich.edu or 734-764-0248.

John Woodrooffe heads UMTRI's Transportation Safety Analysis Division. He is responsible for the Center for National Truck and Bus Statistics, which conducts nationwide surveys of Trucks Involved in Fatal Accidents (TIFA) and Buses Involved in Fatal Accidents (BIFA), and the Statistical Analysis Group, which performs analytical modeling and conducts research to advance statistical methods for road and vehicle safety analysis. He is an international expert on policy and safety evaluation of combination vehicles. Prior to joining UMTRI, Mr. Woodrooffe founded the Road Vehicle Research Program at the National Research Council of Canada and developed it into a successful, internationally-active heavy truck research laboratory. He has also served as chair of the Large Truck-Tractor Trailer working group for the 21st Century Truck Program through the U.S. Department of Energy. The program evaluated vehicle systems and forecasted the probable influence of emerging technology on fuel consumption and vehicle emissions. He can be reached at jhfw@umich.edu or 734-764-0248.

Paul E. Green is Assistant Research Scientist in the Transportation Safety Analysis Division at the University of Michigan Transportation Research Institute. Dr. Green's research interests are focused on statistical modeling of crash data collected from complex sample surveys that include clustering, stratification, and weights. He is interested in data analysis of factors associated with risk to large trucks. In addition, he has developed Bayesian hierarchical models using Markov chain Monte Carlo sampling that generalize existing traffic models for accident rates. His other interests include analysis of exposure data and development of statistical methods for handling missing exposure data. He can be reached at pgreen@umich.edu or 734-764-0248

Acknowledgements

We would like to thank Helen Spradlin of UMTRI for her hard work in managing the telephone and web survey for this project.

Appendix A: Additional Analyses

Larger companies are more familiar with how onboard safety technologies work.

Figure 10: Familiarity with Land Departure Warning Systems

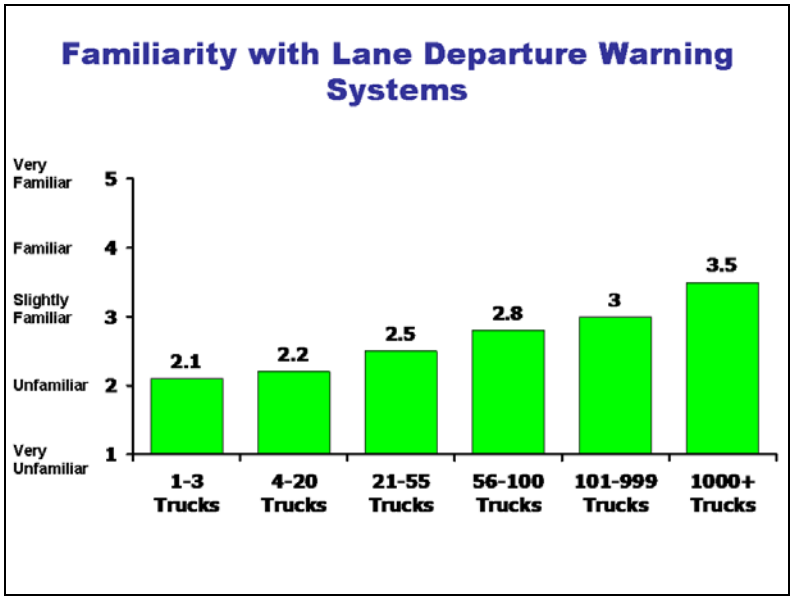


Figure 11: Familiarity with Stability Control Systems

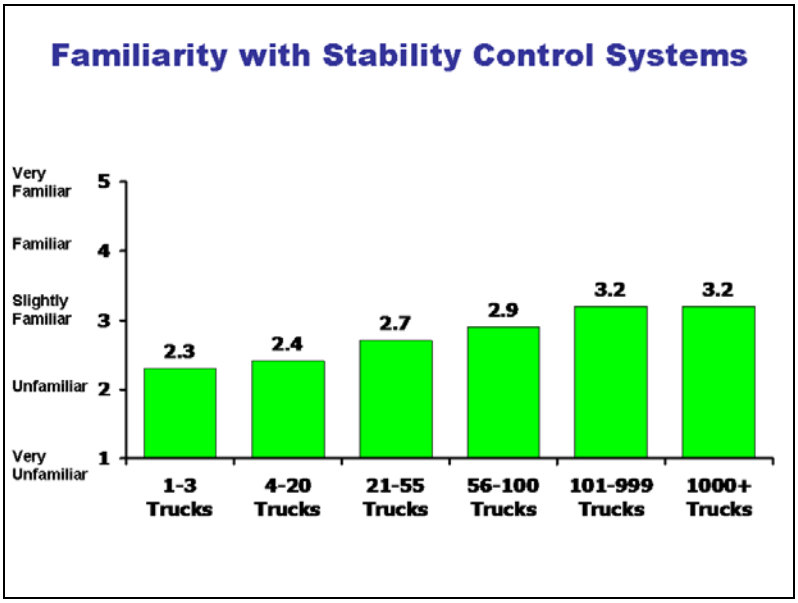


Figure 12: Familiarity with Forward Collision Warning Systems

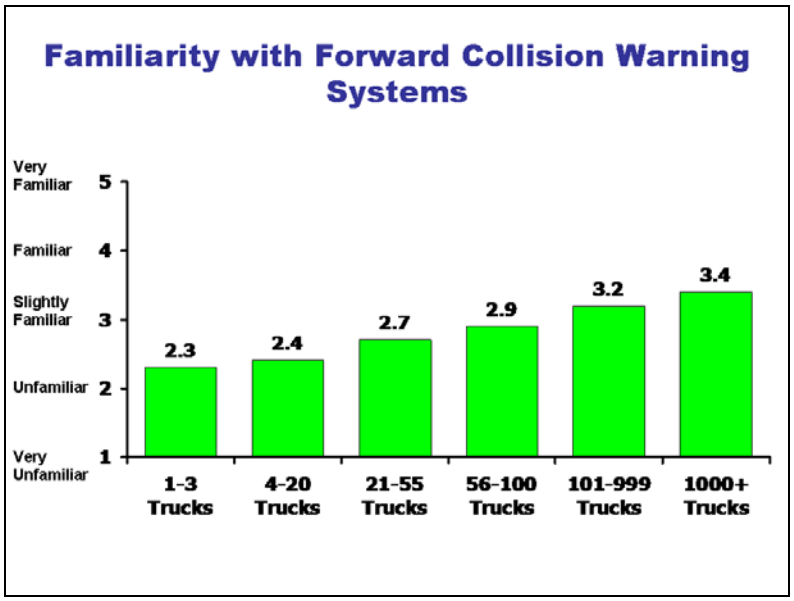


Figure 13: Familiarity with Side Collision Warning Systems

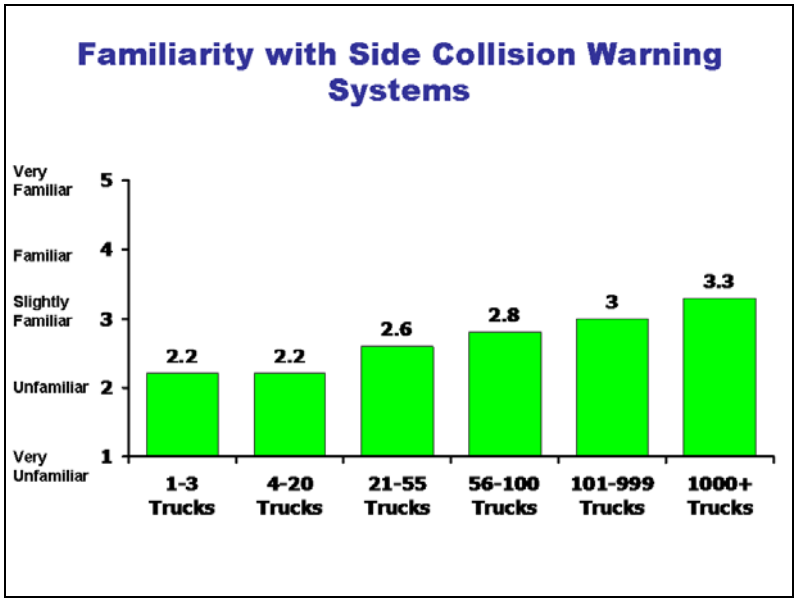


Figure 14: Familiarity with Vehicle Tracking Systems

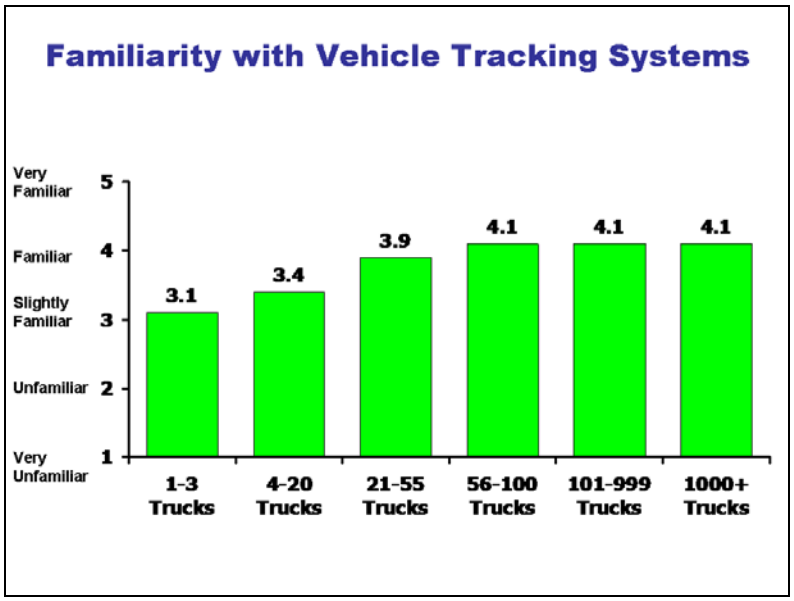
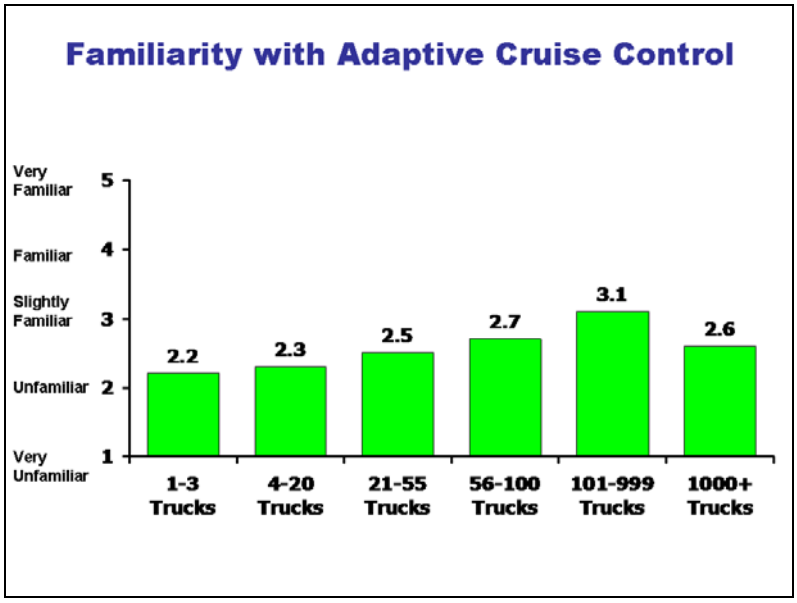


Figure 15: Familiarity with Adaptive Cruise Control



Larger companies are more likely to use onboard safety technologies.

Figure 16: Percent of Companies Currently Using Lane Departure Warning Systems

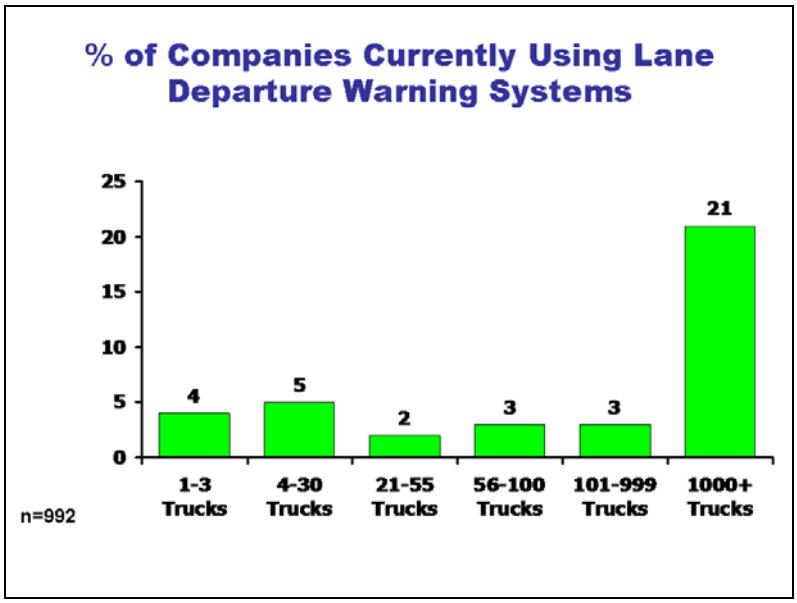


Figure 17: Percent of Companies Currently Using Stability Control Systems

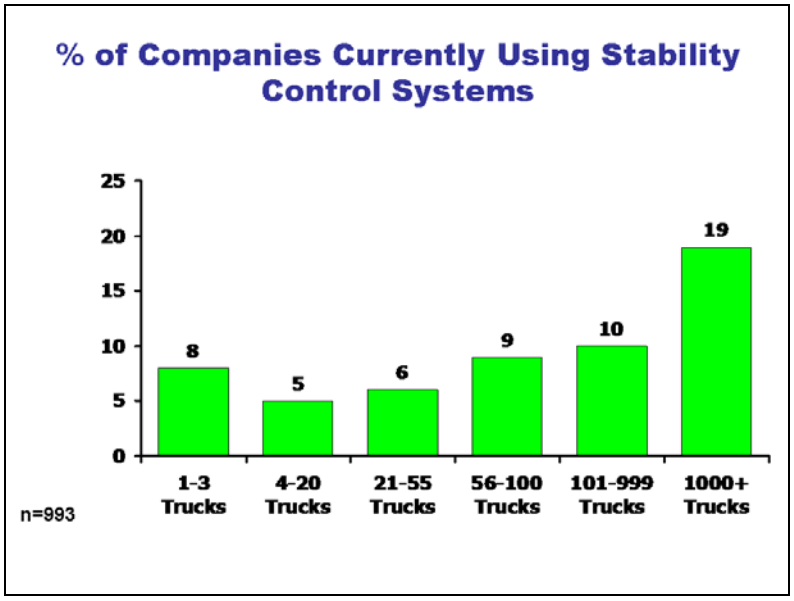


Figure 18: Percent of Companies Currently Using Forward Collision Warning Systems

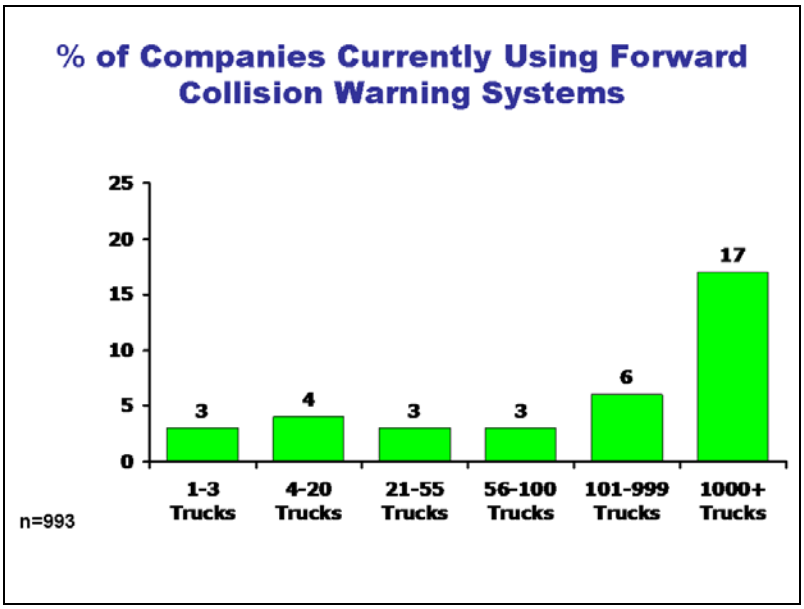


Figure 19: Percent of Companies Currently Using Side Collision Warning Systems

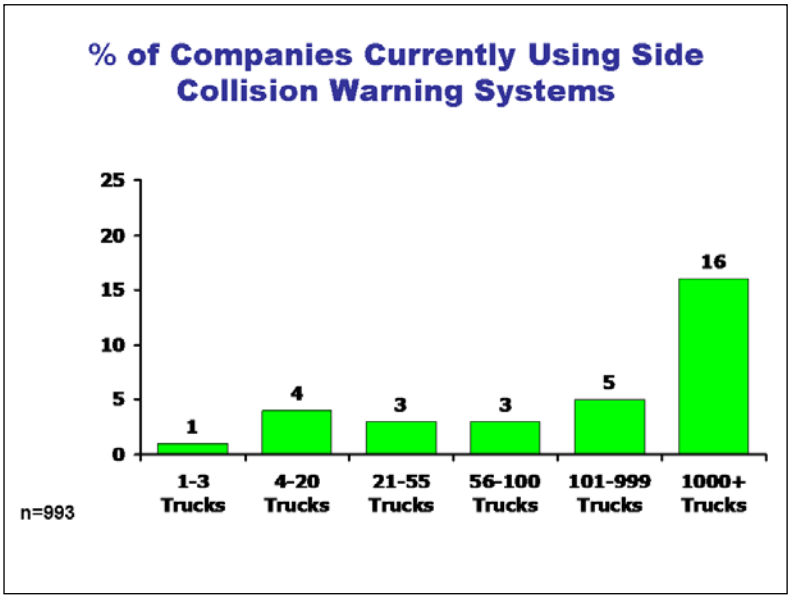
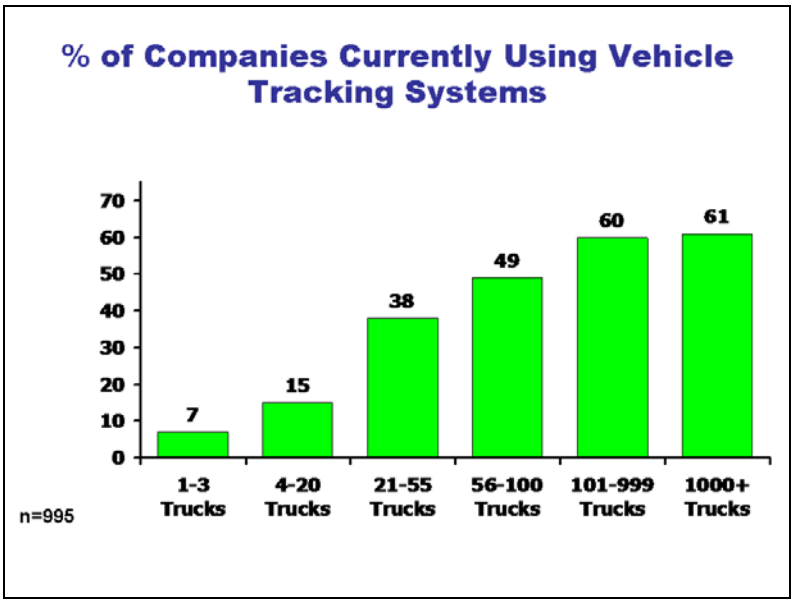


Figure 20: Percent of Companies Currently Using Vehicle Tracking Systems



Carriers report other reasons for using onboard safety technologies.

Figure 21: Other Reasons for Using LDWS, ESC, FCWS, and SCWS

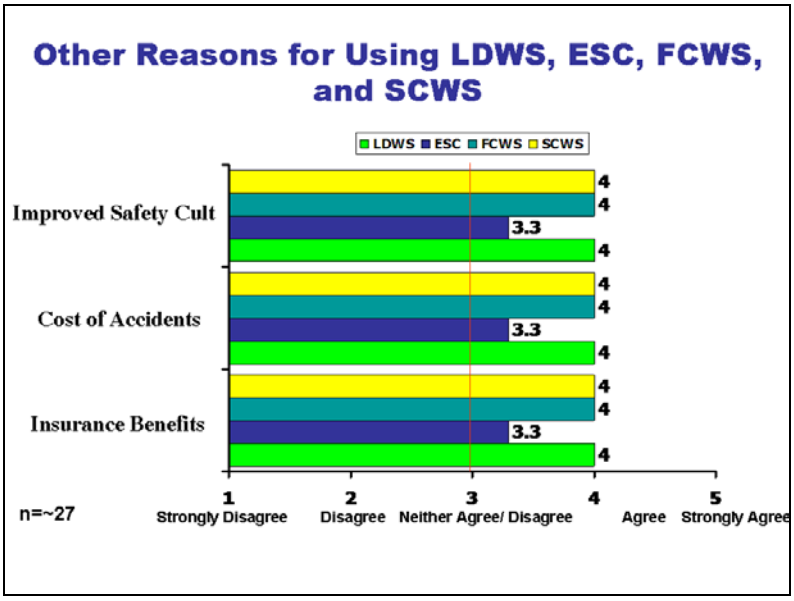
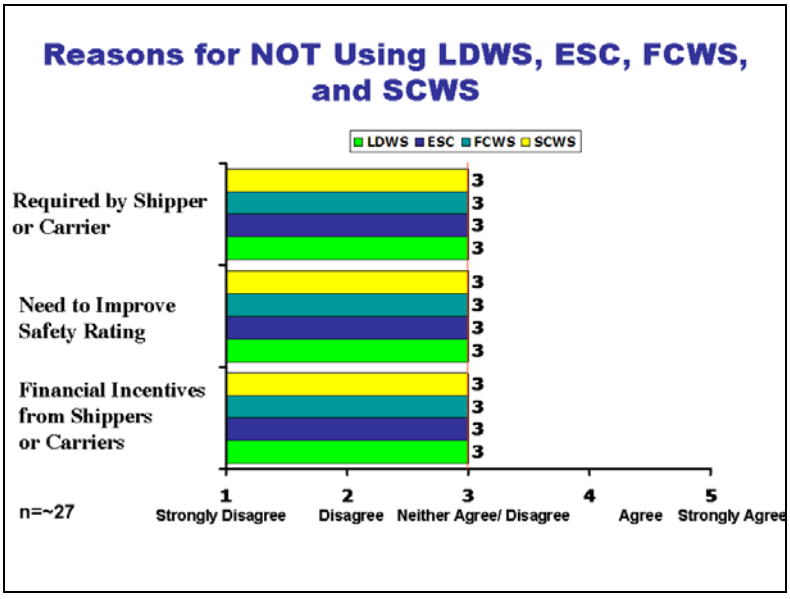


Figure 22: Reasons for NOT using LDWS, ESC, FCWS, and SCWS



Appendix B

Company Demographics

Figure 23: Percent Haz Mat Trips and For Hire vs. Private Business

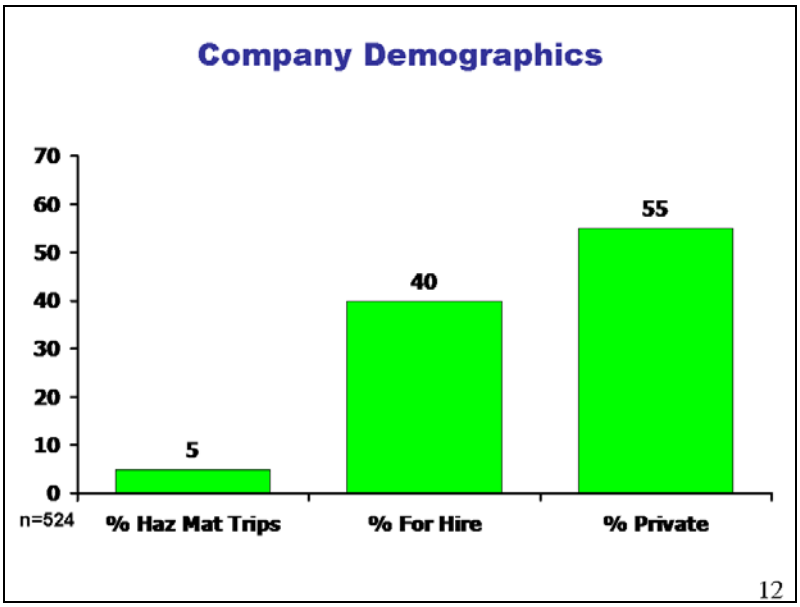


Figure 24: Average Number of Tractors in a Fleet by Strata

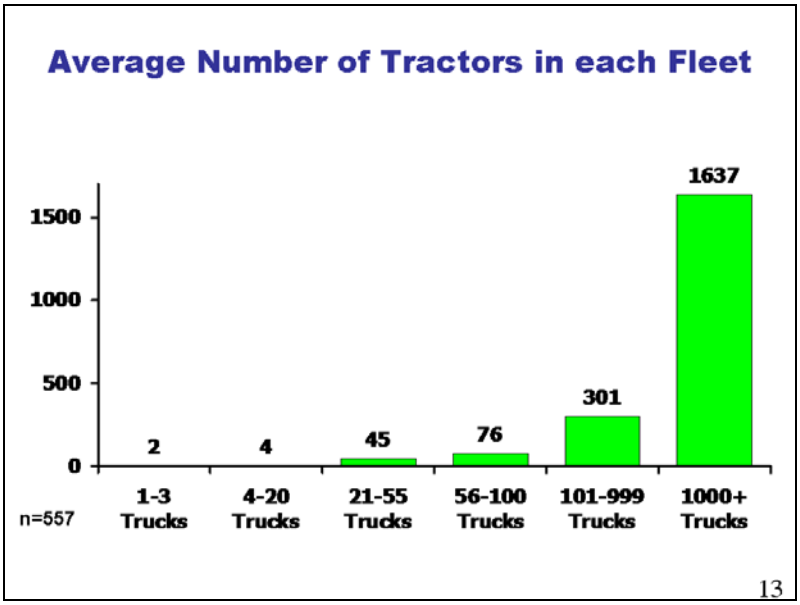


Figure 25: Average Number of Trailers in a Fleet by Strata

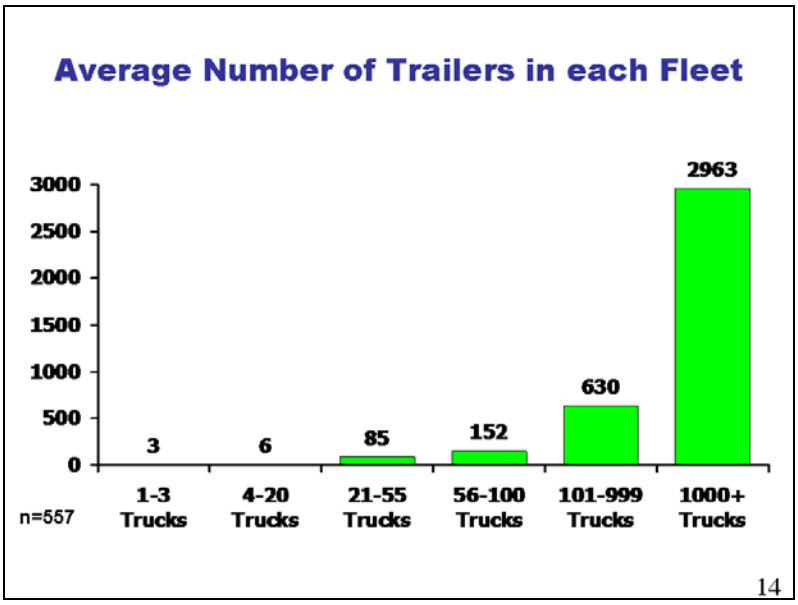


Figure 26: Average Number of Straight Trucks in a Fleet by Strata

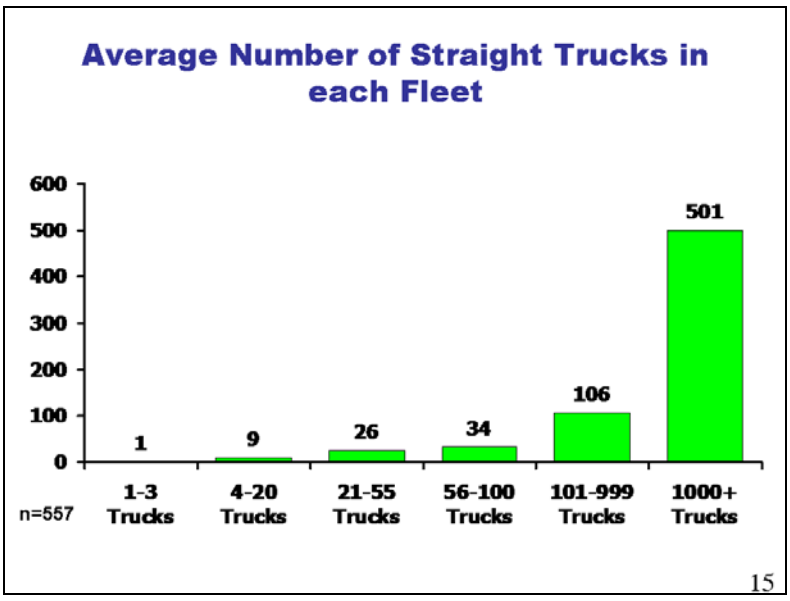


Figure 27: Percent of Companies with Same Day Versus More Than One Day Deliveries

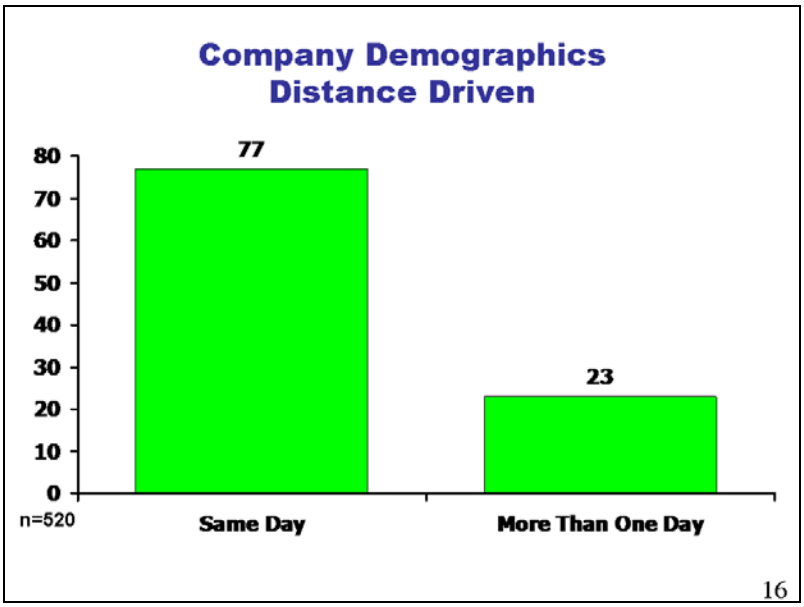


Figure 28: Number of Years Before Replacement of Tractors by Strata

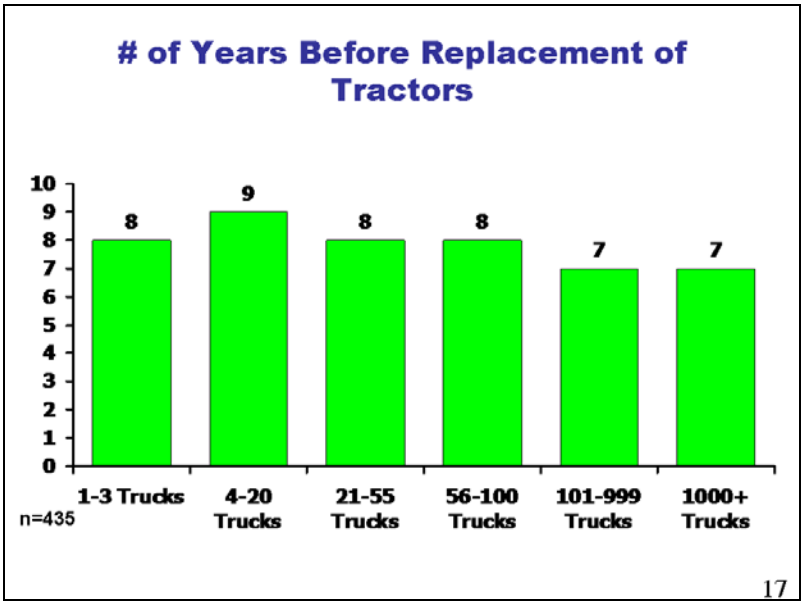
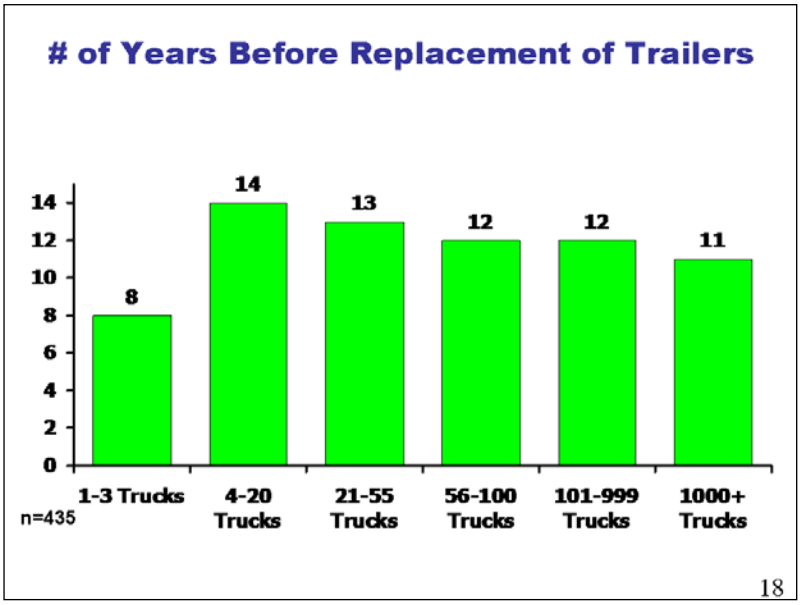


Figure 29: Number of Years Before Replacement of Trailers by Strata



Appendix: C: 95% Confidence Intervals

Table 8: Familiarity with Lane Departure Warning Systems by Strata

Strata	Mean	Confidence Interval: Lower Bound	Confidence Interval: Higher Bound
Strata 1: 1-3 Trucks	2.10	1.92	2.28
Strata 2: 4-20 Trucks	2.20	2.00	2.40
Strata 3: 21-55 Trucks	2.48	2.33	2.64
Strata 4: 56-100 Trucks	2.78	2.61	2.94
Strata 5: 101-999 Trucks	3.00	2.84	3.15
Strata 6: 1000+ Trucks	3.47	3.21	3.73
Total	2.13	1.98	2.28

Table 9: Familiarity with Stability Control Systems by Strata

Strata	Mean	Confidence Interval: Lower Bound	Confidence Interval: Higher Bound
Strata 1: 1-3 Trucks	2.33	2.14	2.52
Strata 2: 4-20 Trucks	2.37	2.17	2.57
Strata 3: 21-55 Trucks	2.71	2.54	2.88
Strata 4: 56-100 Trucks	2.87	2.70	3.03
Strata 5: 101-999 Trucks	3.21	3.06	3.37
Strata 6: 1000+ Trucks	3.22	2.98	3.47
Total	2.35	2.19	2.51

Table 10: Familiarity with Forward Collision Warning Systems by Strata

Strata	Mean	Confidence Interval: Lower Bound	Confidence Interval: Higher Bound
Strata 1: 1-3 Trucks	2.28	2.10	2.45
Strata 2: 4-20 Trucks	2.35	2.16	2.54
Strata 3: 21-55 Trucks	2.68	2.52	2.84
Strata 4: 56-100 Trucks	2.91	2.76	3.07
Strata 5: 101-999 Trucks	3.19	3.03	3.35
Strata 6: 1000+ Trucks	3.35	3.12	3.59
Total	2.30	2.16	2.45

Table 11: Familiarity with Side Collision Warning Systems by Strata

Strata	Mean	Confidence Interval: Lower Bound	Confidence Interval: Higher Bound
Strata 1: 1-3 Trucks	2.16	1.98	2.33
Strata 2: 4-20 Trucks	2.17	2.00	2.35
Strata 3: 21-55 Trucks	2.58	2.42	2.74
Strata 4: 56-100 Trucks	2.79	2.64	2.95
Strata 5: 101-999 Trucks	3.01	2.85	3.18
Strata 6: 1000+ Trucks	3.25	3.01	3.49
Total	2.17	2.03	2.32

Table 12: Familiarity with Vehicle Tracking Systems by Strata

Strata	Mean	Confidence Interval: Lower Bound	Confidence Interval: Higher Bound
Strata 1: 1-3 Trucks	3.10	2.90	3.31
Strata 2: 4-20 Trucks	3.42	3.21	3.63
Strata 3: 21-55 Trucks	3.89	3.73	4.05
Strata 4: 56-100 Trucks	4.11	3.99	4.24
Strata 5: 101-999 Trucks	4.12	3.99	4.26
Strata 6: 1000+ Trucks	4.07	3.83	4.31
Total	3.18	3.01	3.35

Table 13: Familiarity with Adaptive Cruise Control by Strata

Strata	Mean	Confidence Interval: Lower Bound	Confidence Interval: Higher Bound
Strata 1: 1-3 Trucks	2.16	1.94	2.38
Strata 2: 4-20 Trucks	2.31	2.09	2.52
Strata 3: 21-55 Trucks	2.54	2.30	2.78
Strata 4: 56-100 Trucks	2.65	2.38	2.92
Strata 5: 101-999 Trucks	3.05	2.70	3.40
Strata 6: 1000+ Trucks	2.60	2.33	2.87
Total	2.19	2.01	2.37

Table 14: Current Use of Lane Departure Warning Systems by Strata

Strata	Mean	Confidence Interval: Lower Bound	Confidence Interval: Higher Bound
Strata 1: 1-3 Trucks	.0405	0.0087	0.0724
Strata 2: 4-20 Trucks	.0526	0.0146	0.0906
Strata 3: 21-55 Trucks	.0243	0.0032	0.0453
Strata 4: 56-100 Trucks	.0251	0.0033	0.0469
Strata 5: 101-999 Trucks	.0313	0.0084	0.0541
Strata 6: 1000+ Trucks	.2073	0.1194	0.2952
Total	.0423	0.0161	0.0685

Table 15: Current Use of Stability Control Systems by Strata

Strata	Mean	Confidence Interval: Lower Bound	Confidence Interval: Higher Bound
Strata 1: 1-3 Trucks	.0811	0.0370	0.1251
Strata 2: 4-20 Trucks	.0526	0.0146	0.0906
Strata 3: 21-55 Trucks	.0631	0.0298	0.0964
Strata 4: 56-100 Trucks	.0905	0.0505	0.1304
Strata 5: 101-999 Trucks	.1027	0.0629	0.1425
Strata 6: 1000+ Trucks	.1928	0.1078	0.2778
Total	.0759	0.0402	0.1116

Table 16: Current Use of Forward Collision Warning Systems by Strata

Strata	Mean	Confidence Interval: Lower Bound	Confidence Interval: Higher Bound
Strata 1: 1-3 Trucks	**.0338**	**0.0046**	**0.0629**
Strata 2: 4-20 Trucks	**.0376**	**0.0052**	**0.0700**
Strata 3: 21-55 Trucks	**.0291**	**0.0061**	**0.0521**
Strata 4: 56-100 Trucks	**.0302**	**0.0064**	**0.0540**
Strata 5: 101-999 Trucks	**.0580**	**0.0274**	**0.0887**
Strata 6: 1000+ Trucks	**.1687**	**0.0880**	**0.2494**
Total	**.0345**	**0.0106**	**0.0584**

Table 17: Current Use of Side Collision Warning Systems by Strata

Strata	Mean	Confidence Interval: Lower Bound	Confidence Interval: Higher Bound
Strata 1: 1-3 Trucks	**.0135**	**-0.0051***	**0.0321**
Strata 2: 4-20 Trucks	**.0376**	**0.0052**	**0.0700**
Strata 3: 21-55 Trucks	**.0291**	**0.0061**	**0.0521**
Strata 4: 56-100 Trucks	**.0302**	**0.0064**	**0.0540**
Strata 5: 101-999 Trucks	**.0491**	**0.0208**	**0.0775**
Strata 6: 1000+ Trucks	**.1566**	**0.0783**	**0.2350**
Total	**.0184**	**0.0024**	**0.0343**

***** The practical lower bound for this question is zero.

Table 18: Current Use of Vehicle Tracking Systems by Strata

Strata	Mean	Confidence Interval: Lower Bound	Confidence Interval: Higher Bound
Strata 1: 1-3 Trucks	**.0676**	**0.0271**	**0.1081**
Strata 2: 4-20 Trucks	**.1504**	**0.0895**	**0.2112**
Strata 3: 21-55 Trucks	**.3835**	**0.3170**	**0.4500**
Strata 4: 56-100 Trucks	**.4850**	**0.4156**	**0.5544**
Strata 5: 101-999 Trucks	**.6000**	**0.5359**	**0.6641**
Strata 6: 1000+ Trucks	**.6145**	**0.5096**	**0.7193**
Total	**.0925**	**0.0583**	**0.1267**

Table 19: Use of Lane Departure Warning Systems in 5 years by Strata

Strata	Mean	Confidence Interval: Lower Bound	Confidence Interval: Higher Bound
Strata 1: 1-3 Trucks	**.0435**	**-0.0401***	**0.1271**
Strata 2: 4-20 Trucks	**.2000**	**-0.0030***	**0.4030**
Strata 3: 21-55 Trucks	**.1759**	**0.1039**	**0.2480**
Strata 4: 56-100 Trucks	**.0752**	**0.0302**	**0.1201**
Strata 5: 101-999 Trucks	**.1716**	**0.1146**	**0.2286**
Strata 6: 1000+ Trucks	**.3333**	**0.1903**	**0.4763**
Total	**.0800**	**0.0040**	**0.1456**

***** The practical lower bound for this question is zero.

Table 20: Use of Stability Control Systems in 5 years by Strata

Strata	Mean	Confidence Interval: Lower Bound	Confidence Interval: Higher Bound
Strata 1: 1-3 Trucks	**.0870**	**-0.0285***	**0.2025**
Strata 2: 4-20 Trucks	**.2000**	**-0.0030***	**0.4030**
Strata 3: 21-55 Trucks	**.1944**	**0.1196**	**0.2693**
Strata 4: 56-100 Trucks	**.1880**	**0.1214**	**0.2546**
Strata 5: 101-999 Trucks	**.2604**	**0.1940**	**0.3267**
Strata 6: 1000+ Trucks	**.2791**	**0.1446**	**0.4135**
Total	**.1143**	**0.0198**	**0.2069**

***** The practical lower bound for this question is zero.

Table 21: Use of Forward Collision Warning Systems in 5 years by Strata

Strata	Mean	Confidence Interval: Lower Bound	Confidence Interval: Higher Bound
Strata 1: 1-3 Trucks	**.0435**	**-0.0401***	**0.1271**
Strata 2: 4-20 Trucks	**.2000**	**-0.0030***	**0.4030**
Strata 3: 21-55 Trucks	**.1667**	**0.0962**	**0.2372**
Strata 4: 56-100 Trucks	**.1119**	**0.0584**	**0.1655**
Strata 5: 101-999 Trucks	**.1716**	**0.1146**	**0.2286**
Strata 6: 1000+ Trucks	**.3409**	**0.2004**	**0.4814**
Total	**.0800**	**0.0041**	**0.1457**

***** The practical lower bound for this question is zero.

Table 22: Use of Side Collision Warning Systems in 5 years by Strata

Strata	Mean	Confidence Interval: Lower Bound	Confidence Interval: Higher Bound
Strata 1: 1-3 Trucks	**.0435**	**-0.0401***	**0.1271**
Strata 2: 4-20 Trucks	**.2000**	**-0.0030***	**0.4030**
Strata 3: 21-55 Trucks	**.1667**	**0.0962**	**0.2372**
Strata 4: 56-100 Trucks	**.0977**	**0.0471**	**0.1484**
Strata 5: 101-999 Trucks	**.1420**	**0.0892**	**0.1948**
Strata 6: 1000+ Trucks	**.2500**	**0.1217**	**0.3783**
Total	**.0798**	**0.0032**	**0.1447**

***** The practical lower bound for this question is zero.

Table 23: Use of Vehicle Tracking Systems in 5 years by Strata

Strata	Mean	Confidence Interval: Lower Bound	Confidence Interval: Higher Bound
Strata 1: 1-3 Trucks	**.1739**	**0.0185**	**0.3293**
Strata 2: 4-20 Trucks	**.4667**	**0.2134**	**0.7199**
Strata 3: 21-55 Trucks	**.5926**	**0.4996**	**0.6855**
Strata 4: 56-100 Trucks	**.6148**	**0.5325**	**0.6972**
Strata 5: 101-999 Trucks	**.7160**	**0.6478**	**0.7842**
Strata 6: 1000+ Trucks	**.7209**	**0.5865**	**0.8554**
Total	**.2488**	**0.1283**	**0.3841**