Motor Carrier Industry Profile Study:
Evaluating Safety Performance by Motor Carrier Industry Segment

by

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Introduction and Overview

The primary mission of the Federal Motor Carrier Safety Administration (FMCSA) is to prevent commercial motor vehicle-related fatalities and injuries. The FMCSA contributes to ensuring safety in motor carrier operations through public education and outreach, as well as regulatory enforcement. The motor carrier industry is highly diverse and competitive, comprised of many unique types of operations and hauling many different types of commodities. In an effort to better understand the diverse nature of this industry and explore safety and operational differences among its major segments, the FMCSA, with the University of Maryland, College Park, undertook the Motor Carrier Industry Profile Study.

This paper examines the recent safety performance of 11 for-hire and 10 private segments of the motor carrier industry. The safety performance differences between individual segments are examined, as well as the differences between the for-hire and private sectors as a whole. In this analysis, safety performance is evaluated according to two driver-related safety measures, two vehicle safety measures, three crash-related measures, and two safety management performance measures. The study used the Motor Carrier Information Management System (MCMIS) and the Motor Carrier Safety Status Measurement System (SafeStat) as its sources. The MCMIS and SafeStat are maintained

by the FMCSA and are populated with data from roadside inspections, FMCSA and State compliance reviews, crashes, and enforcement cases against motor carriers.

The 10 private commodity segments examined in this study were: Building Materials, Bulk Freight, Refrigerated (non-produce), General Freight-Truckload, Household Goods, Intermodal, Large Machinery, Passenger, Produce, and Tank. The 11 for-hire segments examined in this study included the 10 commodity segments referenced above, plus the Less-Than-Truckload (LTL) segment.

The mean scores of each for-hire and private segment are compared, respectively, to its peer segments on each of the nine safety performance measures using a rudimentary (non-inferential) ranking system. For each safety performance measure, a segment receives a ranking (1 = best performing segment; 2 = second best performing segment; etc.) based on its performance relative to all other for-hire or private segments, respectively, analyzed in this study.

It must be noted that the ranking of segments was part of the preliminary analysis of these data. Currently, the researchers have teamed up with Dr. William Horrace of the University of Arizona to conduct in-depth statistical analysis of the segment-by-segment mean scores using Ranking and Selection Theory, a subset of a larger body of statistical inference procedures called "Multiple Comparison Procedures".[1] Researchers hope to discuss the final MCB/MCW results of this statistical analysis at the April 2002 conference.

Data Sources

The Motor Carrier Management Information System (MCMIS) was the primary source of data used in this study. The MCMIS is used by FMCSA to maintain a comprehensive safety record of for-hire and private property and passenger carriers subject to the Federal Motor Carrier Safety Regulations (FMCSR). The MCMIS Census File contains records from over 500,000 entries (e.g., motor carriers, hazardous materials shippers, and registrants), and contains information on each company's identity (name, address), operations classification (type of business), cargo classification (type of cargo carried), and numbers of trucks and drivers within the company.[2] A motor carrier's identifying information is originally collected when the carrier registers with FMCSA when preparing to operate in interstate commerce.

The MCMIS data set also contains an Inspection File, which contains the results of roadside inspections (submitted by States), enforcement actions (taken by Federal personnel against a motor carrier), and compliance reviews (conducted by FMCSA and State safety investigators.)[3] Enforcement actions may include civil penalties or out-of-service (OOS) orders placed against a carrier. Compliance reviews are on-site reviews of a motor carrier's operations, conducted by FMCSA and State personnel to determine the level of compliance with the FMCSRs.

The MCMIS data set also includes a Crash File, which contains data from State police crash reports electronically transmitted to FMCSA.[4] The census, inspection, and crash data are reviewed and updated as new information is collected by FMCSA on a

motor carrier, whether through inspections, compliance reviews, enforcement action, or reportable crashes.

This study also uses data produced by the Motor Carrier Safety Status Measurement System, or "SafeStat", a powerful analytical tool developed by FMCSA and the Volpe National Transportation Systems Center to accurately identify and monitor high-risk motor carriers within the overall motor carrier population.[5] The SafeStat became operational in 1995 and uses MCMIS data as input to evaluating a motor carrier's relative safety fitness. The SafeStat system incorporates current on-road safety performance data for each carrier with on-site compliance review data collected by FMCSA and State safety investigators. All the data are run through an algorithm, with the result being a comprehensive evaluation of a motor carrier's safety performance using four types of data: accident, driver, vehicle, and safety management. Safety event data are normalized to account for a carrier's size or amount of exposure using carrier-descriptive data such as number of power units or the number of roadside inspections. Data are also time-weighted, with the most recent events having greater weight than older ones. Crash data are also severity-weighted, based on the number and type of injuries sustained by victims involved in the crashes.

All the SafeStat data serve to measure a carrier's relative safety fitness and assess its risk of having future crashes. It should be noted that not all motor carriers contained in the MCMIS data set are analyzed by SafeStat. To be assessed by Safestat, a motor carrier has to have experienced at least three inspections with the past 30 months. As such, the number of firms with Safestat data (e.g., those analyzed in this study) is significantly smaller than the total population of carriers contained in MCMIS.

Safety Performance Measures Used

The nine specific safety performance measures examined in this analysis include two driver-, two vehicle-, three crash-, and two safety management-related measures.

Driver Safety Evaluation Area (SEA) is a SafeStat composite value calculated from Driver Inspection Indicator (DII), Driver Review Indicator (DRI), and Moving Violation Indicator (MVI). The DII is based on driver roadside out-of-service (OOS) inspection violations, the DRI is based on violations of driver-related acute and critical regulations discovered during a compliance review, and the MVI is based on serious moving violations recorded in conjunction with roadside inspections. Each inspection is weighted by its age and the number of driver OOS violations found, and then normalized by the number of driver inspections within the last 30 months. A lower Driver SEA value indicates better safety performance.

Total Driver OOS Rate is derived from MCMIS data. The total number of driver OOS violations, divided by the total number of driver inspections experienced by the motor carrier. A lower Driver OOS rate indicates better safety performance.

Vehicle Safety Evaluation Area (SEA) is a SafeStat composite value calculated from the Vehicle Inspections Indicator (VII) and the Vehicle Review Indicator (VRI). The VII is based on the number of vehicle roadside OOS inspection violations and the VRI is based on violations of vehicle-related acute and critical regulations discovered during compliance reviews. Each inspection is weighted by its age and the number of vehicle OOS violations found, and then normalized by the number of vehicle

inspections within the last 30 months. A lower Vehicle SEA value indicates better safety performance.

Total Vehicle OOS Rate is derived from MCMIS data. The total number of vehicle OOS violations divided by the total number of vehicle inspections experienced by a motor carrier. A lower Vehicle OOS rate indicates better safety performance.

Accident Safety Evaluation Area (SEA) is a SafeStat composite value calculated based on Accident Involvement Indicator (AII) and the Recordable Accident Indicator (RAI). The AII uses measures derived from state-reported crash data normalized by the number of power units owned/leased by the motor carrier from MCMIS. The RAI uses measures based on recordable crashes and annual vehicle miles traveled (VMT) data gathered at the most recent compliance review. A lower Accident SEA value indicates better safety performance.

Fatal Crash Rate is derived from MCMIS data. The number of fatal crashes experienced by a carrier divided by the number of power units owned or leased by that carrier. A lower fatal crash rate indicates better safety performance.

Total Crash Rate is derived from MCMIS data. The number of total recordable crashes experienced by a carrier divided by the number of power units owned or leased by that carrier. A lower total crash rate indicates better safety performance.

Safety Management Review Measure (SMRM) is a compliance review measure that uses the number of safety management-related acute and critical violations of FMCSA regulations discovered during a compliance review. A lower value indicates better safety performance.

Enforcement Severity Measure (ESM) is derived from MCMIS data. The number of past (closed) enforcement cases brought against a carrier by FMCSA. This is a general indicator of the commitment to safety by the motor carrier over time (within the last six years). A lower value indicates better safety performance.

These nine measures were selected from a larger list of 23 safety performance measures for which data were collected in this study. Many of the 23 measures are closely correlated, and several serve as direct inputs to others. In an effort to reduce the potential effect of this correlation on the results, researchers selected nine "core" measures in this analysis. These nine measures are fairly representative of the four safety areas of interest in this study: driver-, vehicle-, crash-, and safety management-related areas. Results are discussed in the next section.

Results

Inspection and crash-related data used in this analysis cover inspections and crashes occurring within the 30-month period between March 1998, and September 2000. The compliance review information used in this analysis covers compliance reviews conducted during the 18-month period between March 1999, and September 2000.

Comparison of Individual For-Hire Segments

Arithmetic means for each of the nine safety performance measures were calculated for each for-hire segment and are included in Table 1 at the end of this document. Also included (in parenthesis) are the relative rankings for each segment on

each safety measure. Industry averages represent the weighted means for all for-hire segments combined. Safety performance results discussed here are for the 30-month period between March 1998 and September 2000. Results of note are discussed below.

The ***for-hire Passenger Carrier Segment*** performed very well relative to the other 10 for-hire commodity segments examined. Specifically, it was either the highest ranked (#1 of 11 segments) or 2nd- highest ranked segment (#2 of 11 segments) on 7 of 9 safety performance measures examined. This segment performed relatively well on all types of measures (driver-, vehicle-, crash-related and "other").

The ***for-hire less-than-truckload (LTL) segment*** also performed relatively well compared to the other for-hire segments examined in this analysis. It was either the highest or 2nd-highest ranked segment on 6 of 9 safety performance measures. Specifically, it was the 2nd-highest ranked (#2 of 11) segment on both vehicle-related measures, and the highest ranked (#1) segment on 2 of 3 crash-related measures. However, a single blemish on its safety performance record appeared on the Accident SEA measure, where it was the lowest ranked (#11) of all for-hire segments. The researchers examined the raw crash data for this segment, but found no extreme outliers that might explain this disparity.

The ***for-hire General Freight-Truckload (TL) segment*** exhibited a safety performance profile near the "middle of the pack," but generally fell within the lower-ranked segments (#6-#8 of 11) on all safety measures. Specifically, this segment did not appear as the highest or 2nd-highest ranked sector on any of the nine safety performance measures examined, nor did it appear as the lowest or 2nd-lowest ranked segment on any measure. This is not surprising, due to the limitations of the MCMIS data used in this

analysis. Specifically, as part of the FMCSA registration process, a motor carrier self selects the commodities it currently carries, or expects to carry, as part of its interstate operations. In choosing among commodity classifications, a carrier is not restricted to just one classification (since, in many cases it is not realistic to assume a motor carrier hauls just one commodity type over a sustained period.) Not surprisingly, many carriers select the "General Freight" commodity segment in addition to other, more specialized commodities selected. As such, this particular segment appears to track relatively closely with the industry mean for each measure. A more complete discussion of these data limitations appears later in this paper.

The ***for-hire Refrigerated Foods segment*** was a relatively poor performer compared to all other for-hire segments examined in this analysis. This segment did not appear as either the highest or 2nd-highest ranked segment on any of the nine measures examined, but did appear as the lowest or 2nd-lowest ranked segment on 3 of the 9 measures. Specifically, this carrier group was the lowest-ranked segment on Driver SEA measure and the 2nd-lowest ranked segment on Driver OOS Rate.

The ***for-hire Produce segment*** was a relatively poor safety performer compared to all other for-hire segments examined in this analysis. It did not appear as the highest or 2nd-highest ranked performer on any measure, but did appear as either the lowest or 2ndlowest ranked segment on 5 of 9 safety performance measures examined. It was the 2nd-lowest ranked segment on Driver SEA, Fatal Crash Rate, and Safety Management Review Measure, and the lowest ranked segment on Total Crash Rate and Enforcement Severity Measure.

It must be noted here that while the terms "highest-" and "lowest-" ranked are used to differentiate between segments for each safety measure, the researchers do not intend to imply that any one segment should be considered the overall "best" or "worst." Also, while we have ranked segments on each individual measure, at present we have not yet completed the in-depth statistical analysis. Multiple Comparisons testing of the best and worst segments should be available at the time of the conference and researchers plan to summarize these results at that time. For an in-depth discussion of this analytical procedure, see the paper authored by Dr. William Horrace in the reference section of this paper. In "eyeballing" the data for each safety measure, however, differences in segment means between the highest-ranked (best-performing) and lowest-ranked (worst-performing) segments do appear quite large in some cases.

Comparison of Individual Private Segments

Arithmetic means for each of the nine safety performance measures were calculated for each private segment and are included in Table 2 at the end of this document. Also included (in parenthesis) are the relative rankings for each segment on each safety measure. Industry averages represent the weighted means for all segments combined. Safety performance results discussed here are for the 30-month period between March 1998 and September 2000. Results of note are discussed below.

The ***private Tank Carrier segment*** exhibited a very safe performance profile compared to other private segments examined in this analysis. Specifically, it was the highest ranked (e.g., #1 of 10) private segment on 3 of 9 safety performance measures. It was the highest ranked segment on both driver-related measures and the Safety

Management Review Measure. Additionally, it did not appear as the lowest- or 2nd-lowest ranked segment on any single safety performance measure.

The ***private Household Goods segment*** performed very well relative to other private segments examined in this analysis. It was either the highest- or 2nd-highest ranked segment on 4 of 9 safety performance measures. It was the highest-ranked segment on both vehicle-related measures and the Accident SEA measure. It was the 2nd -highest ranked segment on Fatal Crash Rate. There was one blemish on its safety record though: it appeared as the lowest ranked segment (#10 of 10) on the Driver OOS Rate measure. Companies likely to be represented within this segment might include, for example, furniture manufacturers and distributors.

The private General Freight segment exhibited a relatively poor safety performance profile compared to other private segments examined in this analysis. Carriers represented in this segment were either the lowest or 2nd lowest ranked segment on 3 of 9 measures. It was the 2nd lowest ranked (#9 of 10 segments) on the Driver OOS Rate, and the lowest ranked (#10 of 10 segments) on the Fatal Crash Rate and Total Crash Rate.

The ***private Large Machinery carriers*** also exhibited a relatively poor safety profile when compared to other private segments examined in this analysis. They were the lowest ranked segment (e.g., #10 of 10 segments) on the Vehicle SEA and Vehicle OOS Rate measures. It also did not receive a ranking higher than a #4 on any single safety measure examined in this analysis.

Comparison of For-Hire Versus Private Segments as a Whole

The researchers also explored differences in mean scores between for-hire and private carriers as a whole, to determine if one of these groups displayed a significantly safer performance profile than the other. Results are included in Table 3 at the end of this paper. Two-tailed t-tests were conducted to determine whether there were statistically significant differences between the mean scores of these two groups. See Appendix A for a brief explanation of the t-test procedure. Results indicate that private carriers were generally safer as a group, as they displayed significantly lower mean scores (statistically speaking) on seven of the nine safety performance measures. These seven measures were: Driver SEA, Driver OOS Rate, Vehicle SEA, Accident SEA, Fatal Crash Rate, Total Crash Rate, and Enforcement Severity Measure. The two measures where for-hire carriers displayed significantly lower mean scores than private carriers were Vehicle OOS Rate and Safety Management Review Measure.

Initial Conclusions

Preliminary results from the segment-by-segment analysis of for-hire carriers indicate that the passenger carrier and LTL segments displayed very safe performance profiles relative to the other nine for-hire segments. The for-hire Refrigerated Foods and Produce segments displayed relatively unsafe profiles when compared to all other for-hire segments. In the preliminary analysis of private segments, the Tank and Household Goods carriers displayed very safe performance profiles, while the General Freight and Large Machinery segments displayed relatively poor performance. Additionally, the for-hire carriers were compared to private carriers as a group. Two-tailed t-tests of the

difference in mean scores on each safety performance measure revealed that private carriers as a group exhibited significantly safer performance on seven of nine safety measures. For-hire carriers as a group displayed a significantly safer performance profile on only two measures.

Limitations of Data and Preliminary Analysis

The data set used in this study presented researchers with several limitations. Some of the current limitations will disappear when the statistical analysis is complete. Others will exist until the original data collection methods are revised. The researchers attempted to address each of these issues, as much as possible, to ensure the safety performance analysis was fair to all segments examined and that the results would be useful.

First, several of the 23 original safety performance measures are correlated. For instance, the Driver OOS Rate is one of three inputs to calculating the Driver SEA. The Vehicle OOS Rate is one of two measures used to calculate Vehicle SEA. Also, the Total Crash Rate is partially a function of the Fatal Crash Rate, although fatal crashes comprise only a small number of total crashes. As such, there was some concern that relatively poor performance on one measure will automatically result in poor performance on a second, related one. While this appeared true when we examined the Vehicle OOS Rate and Vehicle SEA, it did not necessarily hold true when we examined Driver OOS Rate and Driver SEA, nor when we examined Total Crash Rate with Accident SEA, Total Crash Rate with Fatal Crash Rate, and Fatal Crash Rate with Accident SEA. Additionally, to further address the effect that a specific type of measure may have on the

results, researchers balanced the types of measures used in the analysis, including two driver-related measures, two vehicle related-measures, three crash-related measures, and two safety management-related measures. As such, there was relatively even representation among the types of measures examined. The thinking was that strong performance by a particular segment in one set of measures (e.g., crash) might be offset by a weak performance on other measures, and that segment would end up in the middle of the pack of segments when all safety performance measures were examined collectively. Effectively, only a segment that exhibited strong performance on multiple types of safety measures rose to the top and was presented in the results as a relatively strong performer in the analysis.

The second limitation of these data has to do with how commodity classification data are collected by FMCSA. A motor carrier seeking to operate in interstate commerce must first register with FMCSA. As part of this registration process, the motor carrier is requested to list the specific commodities it plans to carry while operating in interstate commerce. Since it is realistic to assume that some carriers will haul more than one commodity type, a carrier is free to select multiple commodity classes on the form. As a result, researchers were not able to assign motor carriers to a unique segment in this analysis. As such, a motor carrier that identified itself as carrying two specific types of commodities examined in this analysis would have its safety performance data included in both segments.

Although there was no way around this complication (e.g., we had no ability to assign motor carriers to a single segment if they had indicated they carried two or more commodities), the potential difficulty is that the mean scores for some of the more

common, generalized segments (e.g., General Freight) will presumably track close to the industry means (e.g., since many carriers assigned to different segments will also be assigned to General Freight). That appears to have occurred to some extent in this analysis, as can be seen from examining the raw data for the General Freight Truckload segment relative to the industry means. However, the number of motor carriers included in this analysis is quite large and there are several, more specialized segments (e.g., passenger carriers, tank) where a unique set of carriers was achieved. As such, the mean scores of these more unique segments do diverge from the industry means. Such differences (or lack thereof in the case of some segments) will be studied further in the upcoming statistical analysis.

References

1. "Multiple Comparisons with the Best, with Economic Applications," by William Horrace and Peter Schmidt, Journal of Applied Econometrics (15, 1-26), 2000.

2. "Motor Carrier Management Information System (MCMIS) Census File Documentation," Federal Highway Administration, Office of Motor Carriers, July 1998.

3. "Motor Carrier Management Information System (MCMIS) Inspection File Documentation," Federal Motor Carrier Safety Administration, April 2000.

4. "Federal Motor Carrier Safety Administration (FMCSA) Crash File Documentation," Federal Motor Carrier Safety Administration, March 1999.

5. "SafeStat, Motor Carrier Safety Status Measurement System, Methodology: Version 8.1," Volpe National Transportation Systems Center, October 2000.

Table 1

For-Hire Trucking
Segment-by-Segment Results
Arithmetic Means for Nine Safety Measures
(Numbers in Parenthesis Indicate Relative Ranking on Each Measure)

VARIABLE	BLDG MATS	BULK	COLD FOOD	GEN FRGT LTL	GEN FRGT TL	HH GDS	INTER MOD	MACH LARG	PAS-SEN-GER	PRO-DUCE	TANK	IND AVG
Driver-Related												
Driver SEA	40.41 (7)	37.08 (4)	51.03 (11)	36.52 (3)	43.67 (8)	44.89 (9)	39.04 (5)	39.06 (6)	21.36 (1)	48.57 (10)	36.49 (2)	42.52
Driver OOS Rate	9.36 (6)	8.86 (5)	12.15 (10)	4.76 (1)	11.18 (8)	13.78 (11)	8.08 (4)	9.64 (7)	6.93 (2)	12.06 (9)	7.32 (3)	10.51
Vehicle-Related												
Vehicle SEA	50.23 (9)	47.30 (6)	46.02 (5)	41.33 (2)	47.53 (8)	44.07 (3)	57.23 (11)	51.33 (10)	30.87 (1)	47.49 (7)	44.51 (4)	47.69
Veh. OOS Rate	27.04 (9)	25.53 (8)	23.82 (5)	20.12 (2)	25.25 (6)	23.28 (3)	28.61 (10)	28.95 (11)	18.50 (1)	25.35 (7)	23.33 (4)	25.50
Crash-Related												
Accident SEA	11.67 (7)	9.96 (3.5)	12.85 (8)	30.80 (11)	11.23 (6)	7.86 (2)	14.28 (9)	9.96 (3.5)	7.67 (1)	10.86 (5)	15.82 (10)	11.14
FAT_CR_D (Fatal Crash Rate)	.015 (7.5)	.022 (11)	.017 (9)	.003 (1)	.015 (7.5)	.013 (4)	.014 (5.5)	.014 (5.5)	.007 (2)	.020 (10)	.009 (3)	.016
TOT_CR_D (Total Crash Rate)	.342 (7)	.411 (10)	.363 (9)	.091 (1)	.352 (8)	.302 (5)	.241 (4)	.329 (6)	.219 (3)	.418 (11)	.205 (2)	.348
Others												
Safety Mmgt Review Measure	20.45 (4)	22.88 (9)	21.26 (6)	9.44 (1)	22.17 (8)	29.32 (11)	20.85 (5)	21.53 (7)	17.09 (3)	23.31 (10)	12.66 (2)	21.50
Enforcement Severity Measure	2.50 (5.5)[1]	2.29 (2)	3.12 (10)	2.50 (5.5)[1]	2.60 (8)	2.51 (4)	2.62 (9)	2.43 (3)	1.57 (1)	3.14 (11)	2.51 (7)	2.62

[1] Relative rank values ending in .5 represent those segments where mean scores for two segments were the same.

Table 2

Private Trucking
Segment-by-Segment Results
Arithmetic Means for Nine Safety Measures
(Numbers in Parenthesis Indicate Relative Ranking on Each Measure)

VARIABLE	BLDG MATS	BULK	COLD FOOD	GEN FRGT TL	HH GDS	INTER MOD	MACH LARG	PAS-SEN-GER	PRO-DUCE	TANK	IND AVG
Driver-Related											
Driver SEA	25.89 (3)	25.63 (2)	28.53 (4)	29.40 (6)	30.05 (7)	28.69 (5)	31.17 (8)	34.60 (10)	31.58 (9)	20.70 (1)	27.29
Driver OOS Rate	9.98 (5)	8.33 (2)	9.11 (4)	12.24 (9)	13.84 (10)	8.75 (3)	11.61 (7)	11.75 (8)	10.54 (6)	6.43 (1)	10.11
Vehicle-Related											
Vehicle SEA	47.32 (7)	46.53 (6)	31.58 (2)	38.16 (4)	28.67 (1)	50.50 (8)	56.03 (10)	51.05 (9)	37.16 (3)	42.72 (5)	45.19
Veh. OOS Rate	27.90 (6)	28.56 (8)	16.41 (2)	21.45 (4)	15.18 (1)	28.25 (7)	33.66 (10)	28.81 (9)	19.96 (3)	24.17 (5)	26.53
Crash-Related											
Accident SEA	4.81 (5)	5.32 (7)	7.28 (10)	3.81 (3)	2.74 (1.5)[1]	4.82 (6)	4.13 (4)	2.74 (1.5)[1]	5.83 (9)	5.57 (8)	4.77
FAT_CR_D (Fatal Crash Rate)	.013 (7)	.016 (9)	.011 (5.5)[1]	.018 (10)	.003 (2)	.011 (5.5)[1]	.014 (8)	.000[2] (1)	.010 (3.5)[1]	.010 (3.5)[1]	.013
TOT_CR_D (Total Crash Rate)	.277 (5)	.359 (9)	.224 (4)	.372 (10)	.310 (8)	.199 (2)	.286 (6.5)[1]	.080[2] (1)	.286 (6.5)[1]	.207 (3)	.284
Other Measures											
Safety Mgmt Review Measure	31.53 (4)	32.73 (5)	35.05 (9)	33.89 (8)	28.22 (3)	39.34 (10)	33.84 (7)	26.67 (2)	33.43 (6)	20.52 (1)	30.69
Enforcement Severity Measure	1.48 (7)	1.30 (4)	2.40 (10)	.98 (2)	1.34 (5)	1.08 (3)	1.45 (6)	.14 (1)	2.19 (9)	1.50 (8)	1.49

[1] Relative rank values ending in .5 represent those segments where mean scores for two segments were the same.

[2] Private Passenger Carrier Segment has only 14 valid observations. One carrier's data (Coach Leasing, Inc.) were removed because researchers felt the data had been erroneously entered (e.g., 23 total crashes for 1 power unit within the last 30 months).

Table 3. Two Sample t-Tests for Difference in Means (For-Hire vs. Private)				
Variable	For-Hire Overall Mean	Private Overall Mean	Difference in Means	Statistically Significant?
Driver-Related				
Driver SEA	42.52	27.29	15.23	Yes, $p < .005$
Dr. OOS Rate	10.51	10.11	.40	Yes, $p < .005$
Vehicle-Related				
Vehicle SEA	47.69	45.19	2.50	Yes, $p < .005$
Veh. OOS Rate	25.50	26.53	-1.03	Yes, $p < .005$
Crash-Related				
Accident SEA	11.14	4.77	6.37	Yes, $p < .005$
Fatal Crash Rate	.016	.013	.003	Yes, $p < .005$
Total Crash Rate	.348	.286	.062	Yes, $p < .005$
Safety Management-Related				
SMRM	21.50	30.69	-9.19	Yes, $p < .005$
ESM	2.62	1.49	1.13	Yes, $p < .005$

Appendix A: Testing for the Difference between Two Means

The classical t-test for the difference between two population means assumes that two independent random samples of size n_1 and n_2 are drawn from two populations with means μ_1 and μ_2 and variances σ_1^2 and σ_2^2. Variances of the populations are unknown. Assuming that the two populations of interest are normal, the statistic

$$t = \frac{(\bar{x}_1 - \bar{x}_2) - (\mu_1 - \mu_2)}{s_{\bar{x}_1 - \bar{x}_2}} \qquad \text{where } s_{\bar{x}_1 - \bar{x}_2} = \sqrt{s_{\bar{x}_1}^2 + s_{\bar{x}_2}^2} = \sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}$$

has a *t*-distribution with approximately $(n_1 + n_2 - 2)$ degrees of freedom.

For each of the nine safety performance measures in this study, the null hypothesis for testing the difference between for-hire and private component means is

$H_0 : \mu_{\text{FOR-HIRE}} - \mu_{\text{PRIVATE}} = 0$. The test statistic used to test this null hypothesis is

$$t = \frac{(\bar{x}_{\text{FOR-HIRE}} - \bar{x}_{\text{PRIVATE}}) - (\mu_{\text{FOR-HIRE}} - \mu_{\text{PRIVATE}})}{\sqrt{\frac{s_{\text{FOR-HIRE}}^2}{n_{\text{FOR-HIRE}}} + \frac{s_{\text{PRIVATE}}^2}{n_{\text{PRIVATE}}}}}$$

where

$\mu_{\text{FOR-HIRE}}$ = the population mean of the for-hire component

μ_{PRIVATE} = the population mean of the private component

$\bar{x}_{\text{FOR-HIRE}}$ = the sample mean of the for-hire component

$\bar{x}_{\text{PRIVATE}}$ = the sample mean of the private component

$n_{\text{FOR-HIRE}}$ = the number of carriers in the for-hire component

n_{PRIVATE} = the number of carriers in the private component

$s_{\text{FOR-HIRE}}^2$ = the sample variance of the for-hire component

s_{PRIVATE}^2 = the sample variance of the private component and

$\sqrt{\frac{s_{\text{FOR-HIRE}}^2}{n_{\text{FOR-HIRE}}} + \frac{s_{\text{PRIVATE}}^2}{n_{\text{PRIVATE}}}}$ is the estimated standard error of the difference between means.

The number of carriers by industry segment varies, which should be taken into account in the calculation of the sample means and variances for the for-hire and private components. For the for-hire component average, the segment sample means are weighted to reflect the different number of carriers in each of the eleven segments, as shown below. Similarly, the sample mean for the private component average is a weighted mean, reflecting the number of carriers in each of ten segments.

$$\bar{x}_{\text{FOR-HIRE}} = \frac{n_1\bar{x}_1 + n_2\bar{x}_2 + \ldots + n_{10}\bar{x}_{10} + n_{11}\bar{x}_{11}}{n_{\text{FOR-HIRE}}}$$

$$\bar{x}_{\text{PRIVATE}} = \frac{n_1\bar{x}_1 + n_2\bar{x}_2 + \ldots + n_9\bar{x}_9 + n_{10}\bar{x}_{10}}{n_{\text{PRIVATE}}}$$

In order to estimate the standard error of the difference of means, the variance estimator for each component's weighted mean was constructed. For the for-hire component weighted mean,

$$v(\bar{x}_{\text{FOR-HIRE}}) = v\left(\frac{n_1\bar{x}_1 + \ldots + n_{11}\bar{x}_{11}}{n_{\text{FOR-HIRE}}}\right)$$

$$= \frac{1}{n^2_{\text{FOR-HIRE}}} v(n_1\bar{x}_1 + \ldots + n_{11}\bar{x}_{11})$$

$$= \frac{1}{n^2_{\text{FOR-HIRE}}} \left[n_1^2 v(\bar{x}_1) + \ldots + n_{11}^2 v(\bar{x}_{11})\right]$$

$$= \frac{1}{n^2_{\text{FOR-HIRE}}} \left[n_1^2\left(\frac{s_1^2}{n_1}\right) + \ldots + n_{11}^2\left(\frac{s_{11}^2}{n_{11}}\right)\right]$$

$$= \frac{1}{n^2_{\text{FOR-HIRE}}} \left(n_1 s_1^2 + \ldots + n_{11}s_{11}^2\right)$$

$$v(\bar{x}_{\text{FOR-HIRE}}) = \frac{n_1 s_1^2 + \ldots + n_{11}s_{11}^2}{n^2_{\text{FOR-HIRE}}}$$

Similarly, the variance estimator for the private component is

$$v(\bar{x}_{\text{PRIVATE}}) = \frac{n_1 s_1^2 + \ldots + n_{10}s_{10}^2}{n^2_{\text{PRIVATE}}} \quad .$$