SAFETY TECHNOLOGIES AND MANAGEMENT PRACTICE FOR IMPROVED FLEET SAFETY

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ABSTRACT

This paper examines truck driver assessment of onboard truck safety technology and management practice including oversight and coaching to estimate the relative effectiveness of technology and management practices on safety performance. The effectiveness assessment is based upon clinical analysis of seven fleets having strong record of safety technology investment. The study examined fleets with strong safety performance and safety monitoring record in order to understand what technologies bring greatest benefit and what management practices maximize the return on safety technology investment.

Researchers conducted on-site visits with each participating fleet, interviewed senior management personnel and conducted a comprehensive driver survey of a subset of fleets to obtain a balanced assessment of systems performance from management and driver perspectives.

The various technologies are assessed by driver opinion and correlated to fleet safety performance. The study found strong correlations between safety technology investment, driver attitude and company management practice with fleet safety performance.

Keywords: Commercial vehicle, truck, safety, safety technology, management, risk assessment, crash avoidance, in-cab camera, driver performance, safety culture, best practice.

INTRODUCTION

This study examined at a case study level seven truck fleets different operating characteristics. The Principal Researcher visited each company on site to discuss the operations, safety equipment used and the safety policies in place and to review safety data. Information obtained included safety programs, incentives and award systems, policy implementation history, driver performance information, crash data, and distance travelled.

A formal driver survey was conducted in accordance with the University of Michigan University of Michigan Health Sciences and Behavioral Sciences Institutional Review Board approval process and the completed surveys were coded by the University of Michigan Institute for Social Research. The findings from the company interviews and safety system analysis were combined with the results of the survey to determine what safety technologies were considered most effective and to determine what safety policies and practices provide the best safety outcome. The study also provides an estimate of the relative benefits associated with safety technology and active safety management practices.

Safety culture is defined as the "norms, attitudes, values, and beliefs held by members of an organization." It is developed by leadership, not only through one-on-one interaction, but also through official policies, memos, e-mails, mass communication. Studies that show that the desired safety culture has to be communicated and developed intentionally (Short, Boyle et al. 2007). Organizations that value safety and communicate that value effectively through supervisors and managers to drivers, operate more safely and have drivers with higher motivations to drive safely (Newnam, Griffin et al. 2008; Peng, Boyle et al. 2010)

Safety is broadly defined as the condition where adverse events are avoided and actions and procedures are implemented to prevent them (Short, Boyle et al. 2007). Developing a safety culture begins with the understanding that all "adverse events," be they traffic crashes or slip-and-falls, can be prevented or at least mitigated. Some authors have claimed that the term "accident" implicitly carries with it the implication of an event that cannot be prevented. The evidence is weak and the insistence on purging the word a distraction, but the point that there must be a commitment and purpose to eliminate all accidents, or hazardous events, is entirely valid and well-supported throughout the literature as critical to developing a safe work environment.

Finally, driver selection, training, and retention is identified as aa key strategy for improving safety outlined by (Knipling, Hickman et al. 2003).

MEASURING SAFETY PERFORMANCE

The companies participating in this study are heavily invested in safety technology and have active safety management programs. Consequently, these companies have very few crashes. To assess the safety performance of exemplary companies, it was determined that crash frequency and travel exposure data were not robust enough to generate reliable crash rates. As an alternative means of assessing safety performance, selected CSA Behavior Analysis and Safety Improvement Categories (BASICs) were used. These measures are generated by Federal Motor Carrier Safety Administration (FMCSA) as part of their safety compliance and enforcement program. They provide a reliable independent means of assessing safety performance that can be applied to any fleet for comparative analysis (FMCSA "Safety Measurement System).

To assess company safety performance for this particular study only the following select BASIC measures were used:

- Unsafe driving
- Hours of service
- Vehicle maintenance.

For the purpose of this study these metrics are considered to be the most direct and reliable for quantifying company safety performance over a broad spectrum of carriers. For example, it allows direct comparison using identical metrics for carriers hauling hazardous materials and non-hazardous materials. The comparative safety score metric was defined as the aggregate of the selected BASICs listed above.

$$\text{Safety Score} = \text{unsafe driving} + \text{hours of service} + \text{vehicle maintenance}$$

SAFETY TECHNOLOGY

The following safety technologies were considered in this study. The technologies were treated as generic with no special consideration for brand or trade name.

1. Stability control – This includes electronic stability control (ESC) and Rollover Stability Control (RSC). These technologies work in the background and will automatically de-throttle the engine, and initiate braking without driver involvement when the system detects loss of control or vehicle over-speed in a curve.
2. Lane keeping/departure – Monitors vehicle lateral position in the travel lane and issues a warning if the vehicle begins to leave the travel lane. The system becomes inactive when the driver uses the turn signal indicator during a lane change maneuver.
3. Over-speed alert system – This system uses an electronic map containing posted speed limit data, and issues an alert if the driver exceeds the posted speed limit on a particular road section.
4. Adaptive cruise control – Uses radar and in some cases integrated vison systems to monitor the traffic ahead of the vehicle containing the technology. The driver selects a cruising speed and the system monitors the gap to the lead vehicle. When the following distance become too small, the engine is de-throttled and if necessary brakes are applied automatically.
5. Forward collision control and braking – This technology uses the same sensors and control systems as adaptive cruise control. These systems are packaged together. Forward collision control and braking operates in the background. When a potential forward collision is identified, the technology warns the driver. If the condition persists and a collision is imminent, the system will apply the foundation brakes to reduce the impact speed.
6. Electronic log book - Electronic Logging Devices (ELDs) monitor driver hours of service to improve compliance with the safety rules that govern the number of hours a driver can work.
7. Automated transmissions – These are often referred to as automated manual transmissions. They eliminate the need for the driver to change gears while in forward motion. These systems behave similar to an automatic transmission in an automobile.
8. Disc brakes – Disc brakes use a rotor disc and a set of friction pads in place of the old style brake-drum and brake-shoe systems often referred to as “S” cam brakes. They have

superior brake performance and do not have the brake out-of-adjustment problems associated with the "S" cam brake systems.

9. In-cab cameras – These cameras are focused on the driver and are triggered during hard braking or significant lateral- or steer-events. Fleets have the option of having film clips associated with triggered events captured for review, which may be used for study, driver coaching, and legal defense.
10. Forward cameras - These cameras are focused on the road ahead of the vehicle. The systems are triggered during hard braking or significant lateral- or steer–events, or by driver request. Fleets have the option of having film clips associated with triggered events captured for review, study, driver coaching, and legal defense.

The safety technologies deployed by the participating fleet is shown in Table 1.

Table 1: Safety technologies in use by participating companies.

Company	ESC	LDW	FCAM	ICC FCC	Blind spot det	Disc brakes	AMT	Safety telemetrics e-log	Speed Limiters	Speed monitoring with GPS
A	yes	yes	yes	yes	yes	yes	yes	yes	58 mph	no
B	yes	yes	yes	yes	no	yes	yes	yes	67 mph	no
C	yes	yes	yes	yes	yes	no	yes	yes	58 short 62 long	no
D	yes	yes	yes	yes	yes	yes	yes	yes	60 –65mph	yes
E	yes	yes	yes	no	yes	yes	yes	yes	65mph	no
F	yes	no	no	no	no	yes	yes	yes	63 mph	no
G	yes	no	no	yes	no	no	yes	Yes	68mph	no

Note: Company C has two distinctive fleets, short haul and long haul. The short haul fleet which is significantly smaller is not equipped with LDW or FWC

ESC – Electronic stability control
LWD- Lane departure warning
OSA - Over speed alert
ACC - Adaptive cruise control
ELB - Electronic log book
FCAM - Forward collision avoidance and mitigation
AMT – Automated manual transmission
DB – Disc brakes
ICC– In-cab cameras
FFC – Forward facing cameras

As shown in Figure 1, the amount of safety technology investment per truck is a strong indicator of overall fleet safety performance. Safety technology investment will have direct safety benefit on its own merits but it may also be a surrogate for commitment to safety by the fleet owner. It is likely that in addition to the investment in technology these fleets also deploy leading safety management practice analytics that promote improved safety culture and performance.

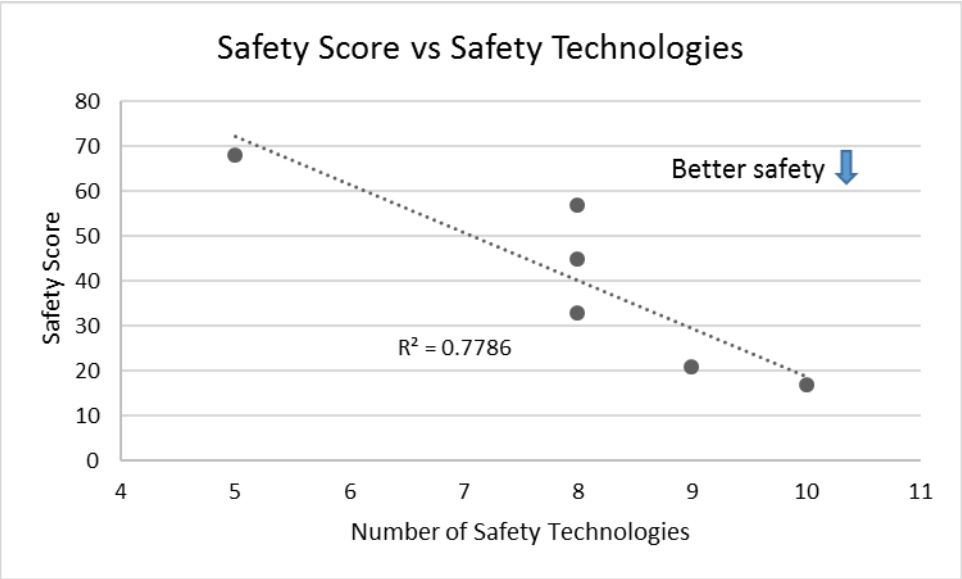

FIGURE 1: Number of safety technologies installed per truck to safety performance

Influence of Fleet Size

The data in Figure 2 shows a correlation between truck fleet size and Safety Score. The reason for this relationship is almost certainly not that fleet size predicts safety, but that larger fleets are more likely and capable of having more resources focused on safety. Smaller companies are less likely to have the resources to provide staff devoted exclusively to safety.

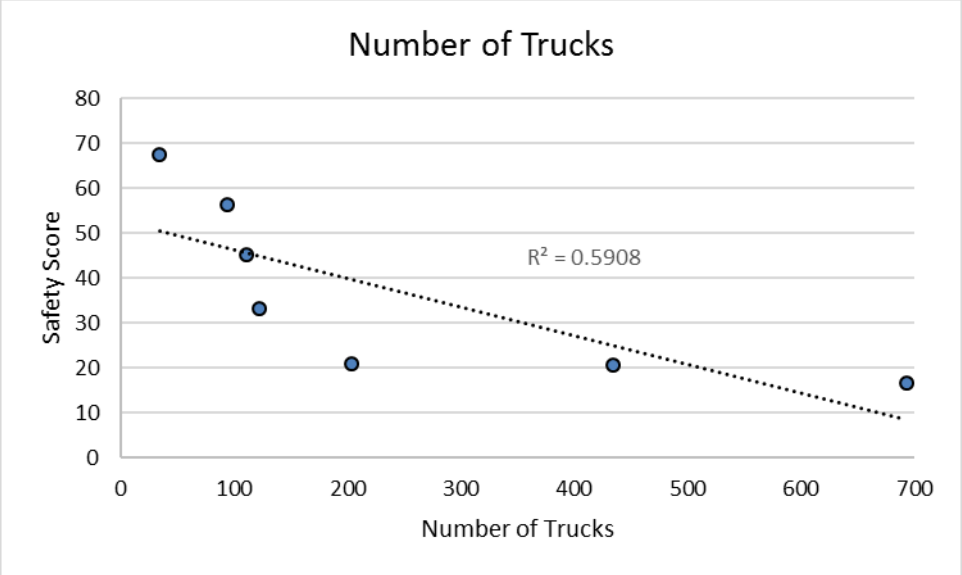

FIGURE 2: Relation of fleet size to safety performance

SURVEY RESULTS

Part One: Demographics: Observations and Findings

1. Driver population was overwhelmingly male with a median driver age of 53 years. The median driver age was approximately the same for all companies.

2. The relationship between driver years with company (tenure) and fleet safety performance is not as prior research suggests it should be. It is likely because most of the participating companies have drivers with long tenure meaning that there is a lack of diversity in the data.
3. Distance travelled per week is correlated with safety outcome. The greater the distance travelled, the lower the safety performance.
4. Percent driving time per day does not appear to be correlated to safety outcome.
5. Driver familiarity with safety policies, is weakly correlated to safety performance improvement.
6. Frequency of organization group safety briefings per year, and individual safety briefings per year is not associated with positive safety outcome. It is likely because most of the participating companies have regular driver meetings meaning that there is a lack of diversity in the data.

Part Two: Thoughts, Feelings and Attitudes: Observations and Findings

Stronger correlation to safety performance.

1. Strongly agree: Confident in your ability to avoid a crash (R-squared 0.33).
2. Strongly agree: Certain you can drive safely (R-squared 0.40).
3. Strongly disagree: Many traffic rules must be ignored to ensure traffic flow (R-squared 0.30).
4. Strongly disagree: It makes sense to exceed the speed limits to get ahead of slow drivers. (R-squared 0.58).
5. Strongly agree: Traffic rules must be respected regardless of road and weather conditions. (R-squared 0.44).
6. Strongly disagree: Speed limits are exceeded because they are too restrictive (R-squared 0.23).
7. Strongly disagree: Taking chances and breaking a few rules does not necessarily make bad drivers (R-squared 0.51).
8. Strongly disagree: It is acceptable to take chances when no other people are involved (R-squared 0.47).
9. Strongly disagree: If you are a good driver it is acceptable to drive a little faster (R-squared 0.68).
10. Strongly agree: Punishments for speeding should be harsher (R-squared 0.54).

Weaker correlation to safety performance.

11. Strongly agree: That you are on top of things when driving (R-squared 0.10).
12. Strongly agree: It is worthwhile to put in effort to improve my driving for my own personal safety (R-squared 0.002).
13. Strongly agree: It is important to maintain safe driving practices at all times (R-squared 0.10).
14. Strongly agree: It is important to drive safely in an effort to reduce the risk of crashes (R-squared 0.10).

The responses to the Part Two survey questions reveal that drivers who are risk adverse are strongly associated with fleets having higher safety performance. These attitudes may have been developed through company policy and coaching and or may be the result screening during the hiring process.

Figure 3 is a plot of the aggregated response scores of all questions in Part Two of the driver survey. The plot shows that safety conscious driver attitude is strongly associated with fleet safety performance.

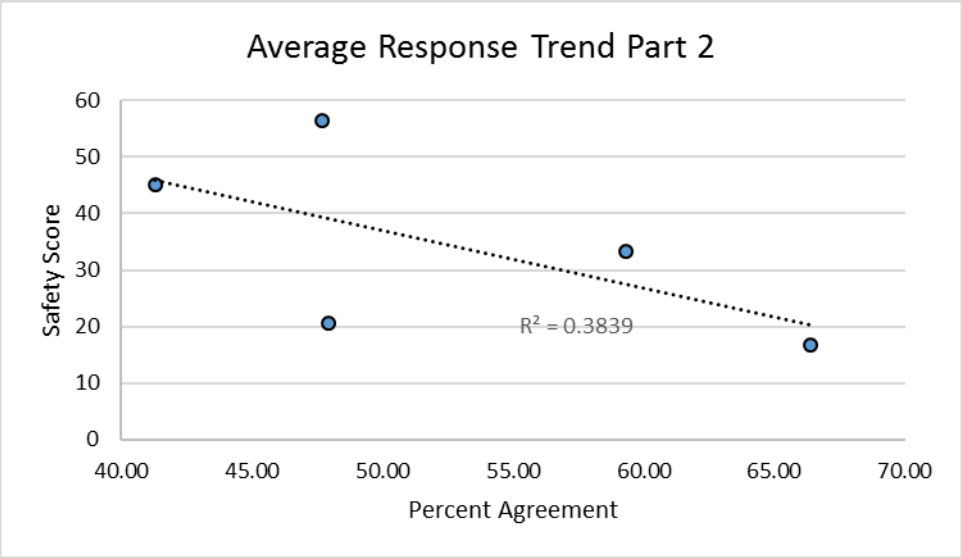

FIGURE 3: Averaged responses from Survey Part 2- Feelings and Attitudes

Part Three: Driver Perceptions: Observations and Findings

Part Three examines driver perceptions of the value and priority given to safety by the company.

Weak correlation to safety performance

1. Strongly agree: My company places a strong emphasis on truck safety (R-squared 0.08).
2. Strongly agree: Truck safety is given a high priority by my company (R-squared 0.07).
3. Strongly agree: My company acknowledges safe driving (R-squared 0.10).
4. Strongly agree: My company respects and values safe drivers in the organization (R-squared 0.12).
5. Strongly agree: My company respects and values safe drivers in the organization (R-squared 0.15).

The pool of drivers participating in the survey were in strong agreement that their companies have a strong safety focus. As shown in Figure 4 there exists a relatively weak but positive correlation between driver perception of company safety focus and fleet safety performance outcome.

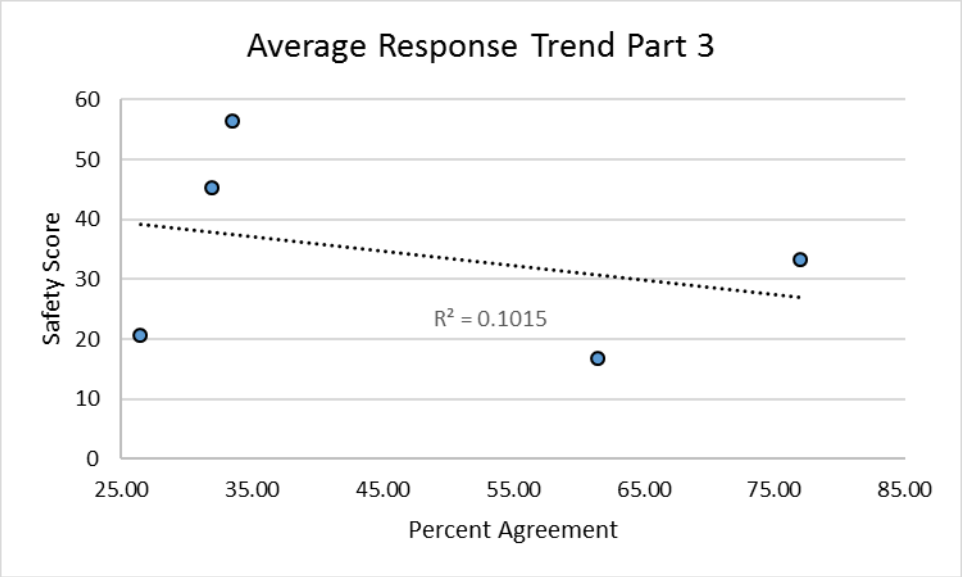

FIGURE 4: Averaged responses from Survey Part 3- Driver Perceptions

Part Four Immediate Supervisor: Observations and Findings

This section examines driver opinion regarding the driver's immediate supervisor who oversees truck driving.

Stronger correlation to safety performance

1. Strongly agree: My immediate supervisor frequently checks to see if drivers are all obeying the safety rules (R-squared 0.40).
2. Strongly agree: My immediate supervisor emphasizes safety procedures when drivers are working under pressure (R-squared 0.27).
3. Strongly agree: My immediate supervisor frequently talks about driver safety issues throughout the work week (R-squared 0.23).

Weaker correlation to safety performance

4. Strongly agree: My immediate supervisor makes sure drivers receive all the equipment/resources needed to drive safely (R-squared 0.13).
5. Strongly agree: My immediate supervisor discusses how to improve safety with drivers (R-squared 0.18).
6. Strongly agree: My immediate supervisor refuses to ignore safety rules when work falls behind schedule (R-squared 0.09).
7. Strongly agree: My immediate supervisor says a "good word" to drivers who pay special attention to safety (R-squared 0.13).
8. Strongly agree: My immediate supervisor respects and values me as a driver and a person (R-squared 0.17).

Stronger correlations to fleet safety performance are associated with questions related to supervisor oversite and constant communications about safety practice. Weaker but significant correlations exist between, provision of safety equipment, coaching, respect and encouragement of drivers. Figure 5 is a plot of the aggregated response scores of all questions in Part Four of the driver survey showing the significant correlation of driver perception of supervisor safety attitude and fleet safety performance outcome.

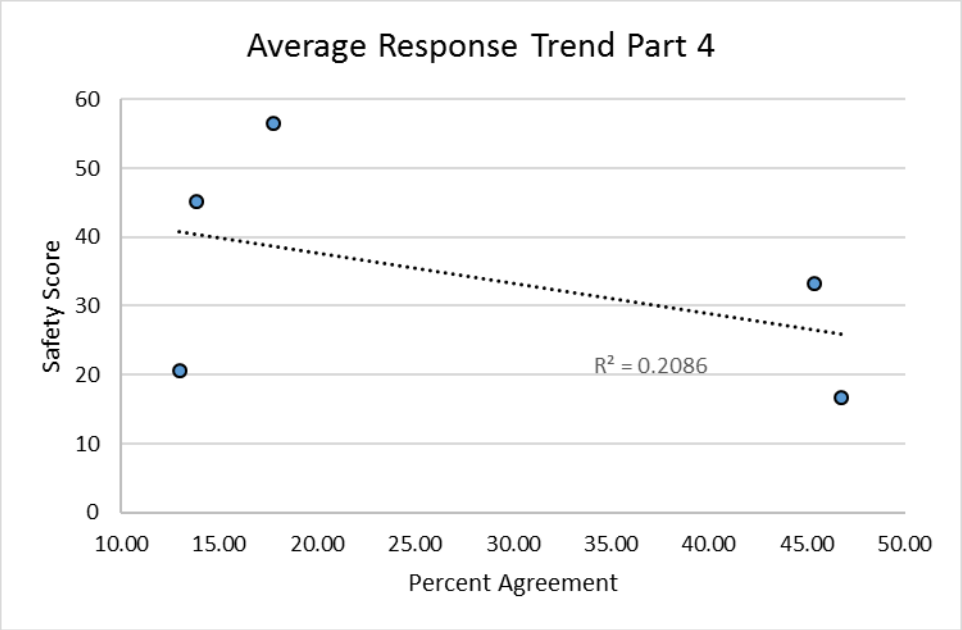

Figure 5: Averaged responses from Survey Part 4- Immediate Supervisor

Part Five Safety Policies and Communication: Observations and Findings

This section examines driver opinion regarding company safety policies and safety communication.

Stronger correlation to safety performance

1. Strongly agree: Truck safety policies and procedures are in place for preventing crashes (R-squared 0.26).
2. Strongly agree: Safety policies and procedures relating to the use of trucks are complete and Comprehensive (R-squared 0.30).

Weaker correlation to safety performance

3. Strongly agree: The truck safety policies and procedures in this organization are useful and effective (R-squared 0.14).
4. Strongly agree: Sufficient opportunity to discuss truck safety (R-squared 0.11).
5. Strongly agree: There is open communication about truck safety issues (R-squared 0.11).
6. Strongly agree: Drivers are regularly consulted about truck safety issues (R-squared 0.01).

Driver perception that fleet safety policies and procedures relating to the use of trucks are complete, comprehensive and are in place to prevent crashes is strongly correlated to fleet safety performance. There is sufficient diversity of opinion among drivers from particular fleets regarding the completeness, comprehensiveness and communication of safety policies and procedures relating to the use of trucks. The stronger the driver agreement as to the complete and comprehensive nature of policies, the better the fleet safety performance, see Figure 6.

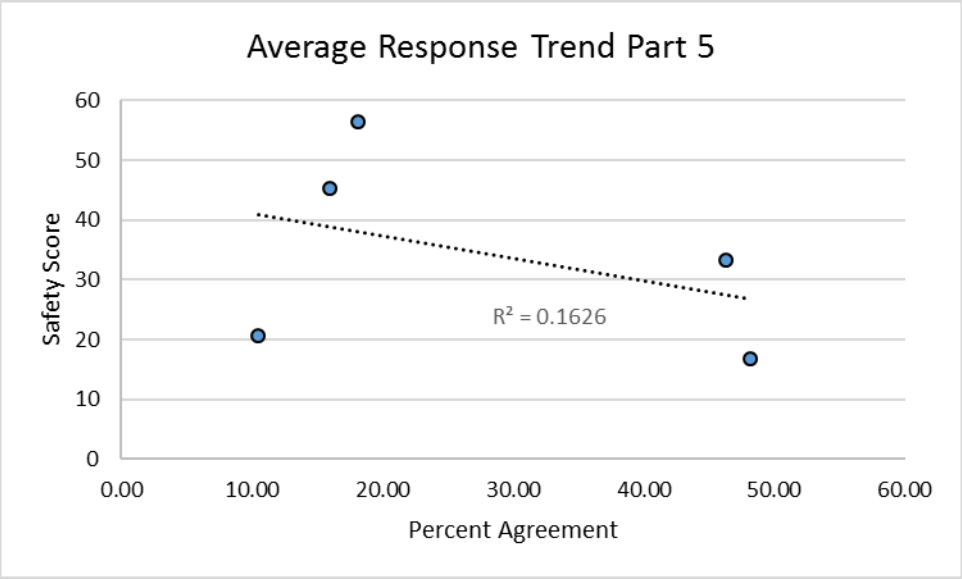

FIGURE 6: Averaged responses from Survey Part 5- Safety Policies and Communication

Part Six Behavior: Observations and Findings

This section examines driver opinion regarding about driver use of a cell phone and other behaviors while driving.

Stronger correlation to safety performance

1. Never - On average, how often do you use your mobile phone when driving your truck? (R-squared 0.46).
2. Never - On average, how often do you text while driving your truck? (R-squared 0.60).
3. Percent - Always wear a seat belt in the terminal yard (R-squared 0.36).

The use of cell phones and texting while driving is very strongly correlated to fleet safety performance. Fleets with drivers that do not use cell phones or text while driving have significantly better safety performance.

Seat belt wearing in terminal yards is also strongly correlated to better safety outcome. Terminal yards are not intrinsically dangerous places in terms of crash severity and it would be expected that many drivers would elect not to wear seat belts in terminal yards. The data clearly show that fleets that convince drivers to wear seat belts in terminal yards have succeeded in establishing a safety culture which yields overall improved safety performance.

Part Seven Vehicle Technology: Observations and Findings

This section asks about truck driver perceptions on in-vehicle safety technology.

Table 2 contains detailed driver ratings of level of acceptance of technologies. Technology acceptance by drivers shows a positive association with higher safety scores.

TABLE 2: How would you rate your level of acceptance of the following technology in your truck?

How would you rate your level of acceptance of the following technology in your truck										
SS	ESC	LDW	OSA	ACC	ELB	FCAM	AMT	DB	ICC	FFC
21	3.79	3.79	3.48	3.72	4.32	3.79	3.94	4.50	2.52	3.82
45	4.00	3.92	3.90	4.06	4.56	3.86	4.50	4.73	3.06	4.05
33	4.29	4.10	3.82	4.53	4.81	4.23	4.58	4.46	3.67	4.55
17	4.22	3.94	4.19	4.19	4.64	3.99	4.09	4.72	3.19	4.21
57	3.84	3.13	3.43	3.57	4.07	3.03	4.19	4.25	2.64	3.50
Total	4.06	3.80	3.84	4.01	4.48	3.80	4.16	4.57	3.06	4.08
Rank	5	8	7	6	2	8	3	1	9	4

0 Not applicable; 1 Not at all accepted; 2 unaccepted; 3 Neutral; 4 Accepted; 5 Fully accepted

SS – Safety Score
ESC – Electronic stability control
LDW- Lane departure warning
OSA - Over speed alert
ACC - Adaptive cruise control
ELB - Electronic log book
FCAM - Forward collision avoidance and mitigation
AMT – Automated manual transmission
DB – Disk brakes
ICC – In-cab cameras
FFC – Forward facing cameras

Table 3 contains data showing the level of driver satisfaction with the safety technologies.

TABLE 3: How would you rate your level of satisfaction with the following technology in your truck?

Rated level of satisfaction with the following technology in truck										
SS	ESC	LDW	OSA	ACC	ELB	FCAM	AMT	DB	ICC	FFC
21	3.25	3.17	2.97	3.00	4.06	2.97	3.40	4.47	2.07	3.07
45	3.80	3.15	3.40	3.28	4.20	3.29	4.64	4.58	2.30	3.40
33	3.76	3.44	3.67	4.17	4.67	3.95	4.71	4.40	3.30	4.15
17	3.71	3.20	3.57	3.72	3.99	3.52	3.86	4.56	2.51	3.66
57	3.55	2.79	2.94	3.28	3.57	2.53	3.95	3.91	2.30	2.83
Total	3.62	3.15	3.32	3.51	4.00	3.27	3.92	4.42	2.49	3.52
Rank	4	9	7	6	2	8	3	1	10	5

Part Eight Onboard Cameras: Observations and Findings

This section examines driver opinion regarding the usefulness of cameras in trucks.

Stronger correlation to safety performance

1. Strongly agree: Agreement with the use of front facing cameras (R-squared 0.25).
2. Strongly agree: Agreement with the use of in-cab facing cameras (R-squared 0.20).
3. Strongly agree: Agreement Front facing cameras are useful for collecting data to defend the driver (R-squared 0.66).
4. Strongly agree: In-cab facing cameras are useful for collecting data to defend the driver (R-squared 0.27).
5. Strongly agree: Front facing cameras is useful for managing the safety of truck drivers (R-squared 0.25).

6. Strongly agree: In-cab facing cameras is useful for coaching and managing the safety of truck drivers (R-squared 0.22).

There is strong correlation between drivers who value the presence and benefits of forward looking and in-cab cameras with fleet safety performance. Diver response data showed that while cameras are not universally appreciated by drivers, fleets with drivers who support their use tend have better safety performance. This suggests that fleets with strong safety performance have successfully educated their drivers on the benefits of cameras. It also suggests that the associated policy governing the use of cameras diminishes driver concern. Figure 7 and 8 shows the relationship between driver understanding of the defensive merits of front facing and in-cab facing onboard cameras and fleet safety performance.

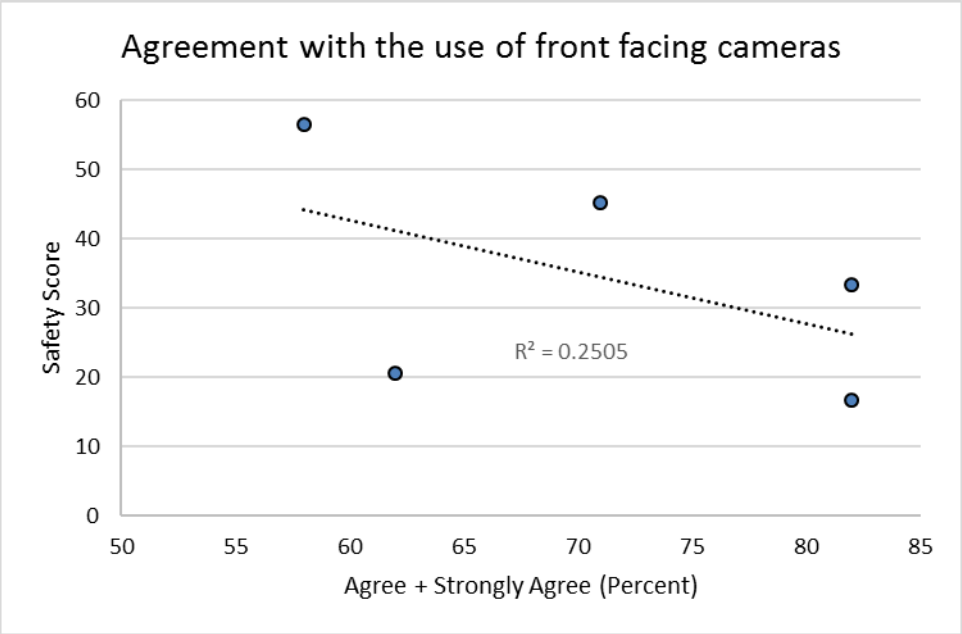

FIGURE 7: Driver opinion of onboard front facing cameras and safety performance

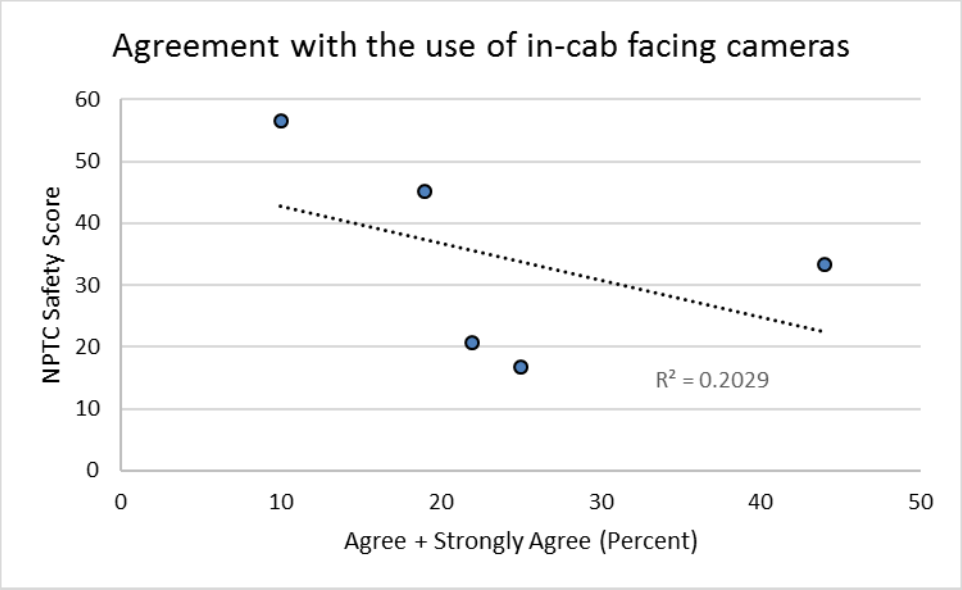

FIGURE 8: Driver opinion of onboard in-cab facing cameras and safety performance

Part Nine: Work Satisfaction: Observations and Findings

This section examines driver opinion regarding overall satisfaction with work.

Stronger correlation to safety performance

1. Strongly agree: Most days I am enthusiastic about my work in this company (R-squared 0.35).

Weaker correlation to safety performance

2. Strongly agree: I am seldom bored with my work in this company (R-squared 0.09).
3. Strongly agree: I feel fairly well satisfied with my work in this company (R-squared 0.05).

No correlation to safety performance

4. Strongly agree: I find real enjoyment in my work with this company (Not positively correlated).

Driver enthusiasm about work is strongly correlated to fleet safety performance. The more enthusiastic that a driver is about work, the better the fleet safety performance. This is likely a reflection of well-developed workplace culture and environment.

Technology Ranking

Driver assessment of the acceptance satisfaction and ranking of the technology is found in Table 4. Disk brakes were the highest ranked technology followed by automatic transmissions and electronic log books. The least favored technologies were lane keeping systems and in-cab cameras.

TABLE 4: Driver assessment of technology acceptance, satisfaction and ranking.

Technology	Acceptance of technology (Percent)	Satisfaction with technology (Percent)	Technology Ranking
Disk Brakes	91	86	1
Auto Transmission	79	71	2
Electronic Log Book	91	69	3
Stability	74	59	4
Cruise Control	74	57	5
Forward Cameras	77	55	6
Over Speed Alert	66	52	7
Forward Collision Control	66	49	8
Lane Keeping	65	43	9
In-Cab Cameras	48	32	10

SUMMARY

The driver survey showed strong and constant association with driver safety culture and knowledge with fleet safety ranking. In particular, strong associations were present in the following areas:

- Driver thoughts, feelings and attitudes with regards to truck driving safety
- Driver perceptions of the value and priority given to safety by the company
- Driver relationship and perceived conduct of the immediate supervisor
- Driver perceptions of truck safety policies and safety communication in the company
- Driver overall satisfaction with work

These perceptions and opinions are likely a reflection of the effectiveness of company culture and policy implementation. The large differences in safety scores among companies with similar types of safety technology content are likely related to the success of particular company safety policies, company attitude towards drivers and the level, the quality of driver coaching and the ability to effectively integrate these elements into safety management practices. This finding strongly suggests that company safety policy dominates safety performance outcome. One may be tempted to conclude that the role of technology is secondary, however in reality it is clearly a required component of successful company safety policy. On the other hand, the implementation of safety technology absent of strong and active safety policies has been shown in this study to provide suboptimal safety benefit.

CONCLUSIONS

1. The amount of safety technology investment per truck is a strong indicator of overall fleet safety performance. Safety technology investment will have direct safety benefit on its own merits but it may also be a surrogate for commitment to safety by the fleet owner. It is likely that in addition to the investment in technology these fleets also deploy leading safety management practice analytics that promote improved safety culture and performance.

2. The data show a correlation between truck fleet size and safety score. A possible reason for this relationship is that larger fleets are more likely and capable of having more resources focused on safety.

3. Safety conscious driver attitude is strongly associated with fleet safety performance. Management practices that promote safe driving attitudes and selecting for risk adverse driver behavior during the driver hiring process and are important contributors to safety outcome.

4. The role of supervisor as a messenger of safety encouragement and company respect towards drivers is correlated to fleet safety performance.

5. The use of cell phones and texting while driving is very strongly correlated to fleet safety performance. Fleets with drivers that do not use cell phones or text while driving have significantly better safety performance.

6. There is strong correlation between drivers who value the presence and benefits of forward looking and in-cab cameras with fleet safety performance. Diver response data showed that while cameras are ranked low in terms of driver acceptance, fleets with drivers who support their use have better safety performance. This suggests that fleets with stronger safety performance have been more successful in educating their drivers on the benefits of cameras.

7. Driver enthusiasm about work is strongly correlated to fleet safety performance. The more enthusiastic that a driver is about work, the better the fleet safety performance. This is likely a reflection of well-developed workplace culture and environment.

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