Fall 2021

Establishing links between safety culture, climate, behaviors, and outcomes of long-haul truck drivers

Carlton Washburn

ESTABLISHING LINKS BETWEEN SAFETY CULTURE, CLIMATE, BEHAVIORS, AND OUTCOMES OF LONG-HAUL TRUCK DRIVERS

by

CARLTON ASHLEY WASHBURN

A DISSERTATION

Presented to the Graduate Faculty of the

MISSOURI UNIVERSITY OF SCIENCE AND TECHNOLOGY

In Partial Fulfillment of the Requirements for the Degree

DOCTOR OF PHILOSOPHY

in

ENGINEERING MANAGEMENT

2021

Approved by:

Dr. Susan Murray, Advisor
Dr. Clair Kueny, Co-Advisor
Dr. Elizabeth Cudney
Dr. Abhijit Gosavi
Dr. Cassie Elrod
Dr. VA Samaranayake

PUBLICATION DISSERTATION OPTION

This dissertation consists of the following two articles, formatted in the style used by the Missouri University of Science and Technology:

Paper I, found on pages 15–30, has been submitted to *Professional Safety*.

Paper II, found on pages 31–64, is intended for submission to Safety and Health at Work.

ABSTRACT

This research examines the safety relationships between safety culture, safety influences, safety climate, and safety outcomes for long-haul truck drivers. The relationships focus on the intersection of the electronic logging device (ELD) technology, regulations, and truck drivers that fall into the lone-worker category. Truck drivers were interviewed to understand their beliefs, attitudes, practices, values, and behavior patterns aligned with the phase in of the ELD system. Large truck crashes during the same time period were analyzed to understand associations. Outcomes included both a safety culture and climate were established for long-haul truck drivers. Both positive and negative safety behaviors were uncovered as a response to the ELD implementation. Crash data aligned with comments from the drivers and showed a sigmoid relationship through ELD phase in. Links between safety culture, safety influences, safety climate, and safety behaviors were established. However, safety behaviors were not connected with safety outcomes.

ACKNOWLEDGMENTS

Thank you to Dr. Susan Murray and Dr. Clair Kueny for their insights, guidance, and coaching. Their help focusing my high-paced industry approach to a methodical academic setting was much appreciated.

Thank you to The Boeing Company who supported my career through the process and partially funded this work.

My wife, Brandi, has been a driving force behind my furthered education, and I appreciate both her patience and support.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

PAPER II Page

NOMENCLATURE

Symbol	Description
N	Number of participatns in the sample
n	Non-specific participate
K	100,000
M	1,000,000

1. INTRODUCTION

1.1. PROBLEM

The number of US workers killed at work each year is appalling. In 2019 there were 5,333 fatalities reported and 2.8 million nonfatal workplace injuries and illnesses (U.S. Bureau of Labor Statistics 2019). There have been improvements in safety at industrial settings, but accidents, injuries, and loss of life still occur. These deaths and injuries are not evenly distributed across the industrial setting. There is a concentration in transportation accidents as reported by the Bureau of Labor Statistics. In 2019 of the 5,333 fatalities 2,122 were due to transportation incidents (U.S. Bureau of Labor Statistics 2019). Almost 40% of all workplace fatalities in 2019 were transportation incidents.

There are many reasons for transportation to top the six categories listed by the Bureau of Labor Statistics. When in a vehicle people feel a sense of autonomy. They are removed from safety reminders in the workplace such as physical hazard markings on floors and safety posters on walls. Drivers are removed from controls and safety systems common in the workplace due to their separation from the workplace. When driving workers are without supervision and contact with their peers, they are independent. With this autonomy drivers have more options to make their own decisions with often quick and deadly results.

Isolated workers such as drivers can be grouped as lone-workers. There is not a single definition that captures lone-workers, rather an awareness that lone-workers perform their jobs away from others in their industry, often in isolation, and often without

access to supervision (Hughes & Ferrett, 2009, BSIA, 2010, Brennan, 2012, Agnew et. al. 2017). Lone-workers include groups such as airline workers, traveling nurses, telecommuters, and truck drivers.

Lone-workers can be difficult to research both due to their isolation and the need to research them in their working environment. It is important to perform research on people in their working environment because that is where the research laboratory is located (Schneider, 1987). Access to workers in their environment is critical to successful research. Gaining access to speak with pilots while they are flying is difficult due to cabin restrictions and airports are controlled environments. Traveling nurses are mandated to follow Health Insurance Portability and Accountability Act (HIPPA) laws making them very difficult to access because of patient privacy laws. Telecommuters are difficult to research since they are operating out of their own home and a challenge to connect with. However, long-haul truck drivers can be researched in their working environment by accessing them at truck stops. This makes the trucking industry a strong candidate for safety research focused on lone-workers.

One of the challenges improving safety in lone-workers such as truck drivers is understanding the links between safety culture, safety climate, safety influences, safety behaviors, and safety outcomes. Safety culture has been defined as not quickly interpreted by outsiders and as a set of common beliefs, attitudes, practices, values, and behavior patterns among a group of people (Cox & Flin, 1998, Mearns and Flin, 1999, Ostroff, Kinicki, A.J., and Muhammad, 2012, Huang, 2013). Safety climate can be considered directly observable by the outside world and it has generally been accepted as shared perceptions of an organization's policies, procedures, and practices (Griffin &

Neal, 2000; Zohar, 1980, 2000). In other words, safety climate can be understood as the priority of safety in an organization. To connect the two concepts of culture and climate, climate is what happens in an organization, whereas culture is why it happens. Safety climate can have links to influences, which in turn tie into safety behaviors that can be connected to safety outcomes. Understanding that these links start with safety culture, can truck drivers even have a safety culture to begin with since it is defined as a set of common attributes? If a safety culture does exist, is it possible for all these links to exist in workers that spend most of their time away from their organization?

1.2. PURPOSE

The purpose of this research is to answer the questions can a safety culture be identified among long-haul truck drivers, what influence does safety technology have on their safety behaviors, and do links exist between safety culture, safety influences, safety climate, and safety outcomes? The last question is if new safety technology is implemented is there a positive association with safety outcomes?

1.3. RESEARCH

To answer these questions a review of past research was completed. This review had to compare areas of safety research that have historically existed in separate domains to be able to study the aforementioned linkages. This work is focused on safety engineering and it also overlaps with both human and organizational behavior. Due to this the literature review also had to bridge the gap between safety engineering and industrial and organizational psychology.

The timing of this research was fortuitous; from 2015 to 2019 a new federally mandated technology system was phased in for long-haul truck drivers (Federal Register 2015). The system was called an electronic logging device (ELD). The ELD was a digital data logging system that took the place of hand recorded logs. The ELD was implemented to improve both driving safety and driving economy. Focusing on the safety aspects of the ELD, the goal was force compliance with driving time limitations and provide assurances that a driver had both regular opportunities and sufficient time to rest. The digital aspect of the ELD was also intended to improve the accuracy of data logging that would in turn provide trucking companies and regulators with data that eliminated both deliberate and accidental errors. The transition into using ELDs became an important part of the research. Not only did it provide an opportunity to study how technology affected safety in truck drivers, but it also provided a widely known topic to start discussions with drivers.

The research was conducted at a Missouri truck stop across several weeks through 2019 and beginning of 2020. After approval from an institutional review board (IRB), semi-structured interviews were conducted with self-identified long-haul truck drivers. The truck stop was chosen to access drivers in their workplace setting without driver's supervisors or colleagues. Candidates were asked if they were a truck driver and if they answered yes, the research process was explained along with a request to fill out a release form and demographic survey, all in exchange for a $10 gift card.

2. LITERATURE REVIEW

2.1. SAFETY ENGINEERING

This research focused on understanding the safety culture of long-haul truck drivers. To understand both the place in safety engineering this research resides and its importance, a review of past research was explored. Safety engineering contains a blend of analysis techniques that use both quantitative and qualitative approaches. These techniques cover designs of devices, processes, systems, and interactions between people and technology. Examples include hazards analysis common in the process industries such as fault tree analysis (FTA) and hazard and operability study (HazOp), and failure mode and effects analysis (FMEA) common in several industries. Fault tree analysis is a top-down method that uses a quantitative approach to identify the root cause of a failure and calculate the probability of failure (Ericson 1999). Hazard and operability studies examine processes by breaking them into smaller pieces called nodes and then using qualitative techniques teams analyze the notes for hazards (Venkatasubramanian 2000, Kletz 1988). Failure mode and effects analysis takes a quantitative approach to systems by analyzing the intended function of the component and then breaking the analysis into failure effects, modes, and causes (Dept. of Defense 1949, Kumamoto 1996, Hawkins 1998).

The methods listed above are traditional hazard analysis methods and are all deductive in their design. These methods start at a more complex level of engineering and then work to analyze specific parts or interactions of the system. The cause-and-effect relationships can be understood because the background research has documented

through academic rigor why these technique work and definitions such as failure modes. This forms a foundation for determining sequences, relationships, and situations that lead to failure. There is also a taxonomy that allows engineers to classify and communicate their results in a commonly understood way (Collins 1976, Tumer 2003, Grantham Lough 2008, Washburn 2012). These techniques have matured due to the knowledge gained over time from the work of many engineers.

The analysis methods focus on technology aspects of systems and exclude interactions with humans. Human factors engineering includes people when analyzing systems. Human factors engineering focuses on the design of systems, methods, and environments that consider the safety, performance, and productiveness of humans (Wickens 2015). Safety is included in human factors engineering and examines the relationship between people and systems. Human factors includes human behaviors which bridges into psychology. Recent examples of this include the influence of mobile phones with human and vehicle interactions (Strayer 2013, Holland 2013, Haque 2014).

2.2. SAFETY CLIMATE

The intersection of engineering and psychology becomes interesting when focusing on the workplace. With the goal of improving safety research needs to move beyond technology aspects of safety and explore how people improve safety, along with the relationship of people and technology in safety. It is not surprising that the people aspect of safety has become a very popular area of research with the rapid growth of safety climate publications in recent years (Bamel 2020, Lou 2020).

Safety research has existed for decades, and Zohar's work in the early 1980s defined the beginning of a new chapter in our knowledge. His work proposed a measurable connection between safety climate and organizational patterns in an organization (Zohar 1980). Safety climate research is important because later research showed that safety climate is a predictor of safety outcomes across several industries (Goldenhar 2003, DeJoy 2004, Neal 2006, Hofmann 2006, Clarke 2010, Lingard 2012, Hon 2014, Anderson 2018). These studies showed a positive correlation between safety climate and safety outcomes such as injury rate.

Safety climate has been defined as directly observable by the outside world, and it has been accepted as shared perceptions of an organization's policies, procedures, and practices (Zohar 1980, 2003, 2011, Griffin 2000, Beus 2010). In short, safety climate can be understood as employee perceptions of how important safety is in their organization (Bergman 2014). More recent work has added understanding that safety climate changes over time and has a shelf-life (Bergman 2014) and explored the strength of safety climate (Vogus 2016, Ginsburg 2016).

In parallel safety culture has also been a focus of research. The earliest reference to safety culture was found in the report on the Chernobyl Reactor Incident by the International Atomic Energy Agency (International Nuclear Safety Advisory Group 1986). This report started to define a safety culture. As research into safety culture was undertaken literature outlined safety culture as a mix of safety engineering, psychology, and human factors. This broad concept of safety culture became too large to the point it was ineffective (Cox 1996). Safety culture and safety climate were used interchangeably

in literature, so to reduce confusion research was focused on defining these two different concepts (Glick 1985, Reichers 1990, Moran 1992, Furnham 2012).

As the millennium came to a close, climate and culture definitions were starting to take shape. Part of the separation was how the research was being performed in regard to climate and culture (Denison 1996). Safety climate researchers were using surveys, which accessed the surface of participant's attitudes and perceptions of safety climate (Mearns 2001). This understanding helped to define both safety climate research methods and define what safety climate was. Since safety climate was partially defined as directly observable by the outside world, surveys that recorded shared perceptions worked well to capture and analyze safety climates across different industries. This created a clear separation between safety climate and safety culture because climate only provides an indication of what a safety culture might contain (Schneider 1990).

With safety climate research now focused on a common definition and surveys as a common tool, a new challenge emerged. The different surveys researchers were using were difficult to compare. Part of the origin for the divergence in surveys was earlier work on safety climate dimensions. Zohar's 1980 work on safety climate defined eight dimensions. They included perceptions of the importance of safety training programs, management attitudes toward safety, effects of safe conduct on promotion, level of risk at the workplace, effects of required work pace on safety, status of safety officer, effects of safe conduct on social status, and status of safety committee (Zohar 1980). Zohar's climate survey was built around these dimensions. The number of dimensions changed with subsequent work and researchers refined their surveys (Brown 1986, Dedobbeleer 1991). As a result of the differences in surveys and difficult to compare results, recent

work has shifted to meta-analysis. Meta-analysis is a quantitative approach to integrate results across different studies and is often used in medical research (Walker 2008). Meta-analysis has been used to compare safety climate survey results across industries (Nahrgang 2007, Christian 2009, Clarke 2010, He 2019, Jiang 2019).

2.3. SAFETY CULTURE

With safety climate research maturing safety culture was following a similar pathway. Safety culture was defined as not quickly interpreted by outsiders and as a set of common beliefs, attitudes, practices, values, and behavior patterns among a group of people (Cox 1991, Mearns 1999, Ostroff 2012, Huang 2013). Researchers had started to separate safety climate and safety culture research. The analogy emerged that culture was associated with personality and climate with mood (Cox & Cox 1996). Part of the understanding that also started to emerge was that safety culture and safety climate exist on different levels. Safety climate is what happens, whereas safety culture is why it happens. Even though safety climate is narrower due to its definition, it can be a reflection of aspects of safety culture. This understanding was important because it indicated there was both a separation between climate and culture, but also links between them. It is generally accepted today that safety culture is the influencing mechanism for safety climates and ultimately safety behavior (Neal 2006, Schneider 2013).

Surveys emerged as the defining mechanism for gathering data on safety climate, but research techniques for safety culture are still being explored. Research methods for safety culture have covered interviews, focus groups, audits, and ratings from experts (Cooke 1989, Roberts 1994, Carroll 1998, Clarke 1999). Safety culture research is

following the pathway of safety climate work and in the nuclear industry safety culture work has started to define dimensions (Lee 1998). In other industries research to understand safety culture is less mature and work on research methods and culture dimensions continue.

2.4. LONE-WORKERS

One of the areas of recent safety interest are lone-workers. Lone-workers do not have a formal definition, rather an understanding that they perform their jobs away from others in their industry, often in isolation, and often without access to supervision (Ferrett 2009, BSIA 2010, Brennan 2012, Agnew 2017). Groups that are associated with lone-workers include traveling nurses, airline workers such as pilots, telecommuters, and long-haul truck drivers. Considering the research methods for safety culture listed above some of these lone-worker groups can be exceedingly difficult to access for research. This is compounded by the fact that safety culture research is about people, so their work environment becomes the laboratory (Schneider 1987). The challenges accessing pilots, traveling nurses, and telecommuters were reviewed in the introduction portion of this dissertation. The trucking industry lacked the access constraints that other lone-workers have. Truck stops are part of long-haul truck driver's work environment and can be accessed by the public. This made the trucking industry a strong candidate for safety research and in the early 2000s safety research started to investigate links to truck driving accidents.

2.5. TRUCK DRIVING SAFETY

Early work in in truck-driving safety started with safety climate and this created an interesting dilemma. Research started by trying to establish a link between safety climate and management by analyzing accidents (Arboleda 2003). The authors assumed that a stronger safety climate would translate to reduced accidents, but their results showed no evidence of this connection. This research was not able to establish the same relationship that a multitude of past studies had shown. The researchers stated that participants were reluctant to acknowledge their responsibility in an accident which may have biased their survey results (Arboleda 2003, Geller 1996). However, a different perspective changed Arboleda's results. With truck-drivers being lone-workers and therefore lacking some of the dimensions of a safety climate, could a safety climate or safety culture exist in lone-workers? If this was assumed to be true it meant that Arboleda's results aligned with the understanding of lone-workers, and that a safety climate and possibly culture could not exist in lone-workers.

The next phase of research examined short-haul truck drivers. Studies showed that safety climate scale predicted safety behaviors of drivers (Wills 2006), and stronger perceptions indicated a stronger safety climate, which aligned with reduced accidents (Wallace 2006), and links between safety climate and occupational stress of drivers were established (Strahn 2008). This work examined short-haul truck drivers who had regular contact with their supervisors and colleagues. So, it made sense that past research into safety climate would translate to short-haul drivers given the similarity in work environments to past climate research areas. However, short-haul drivers are not lone-workers due to their frequent access to supervision and limited isolation. So even though

this work was encouraging, it did not address the dilemma that a lack of safety climate dimensions in lone-workers might mean previously established safety links may not exist in long-haul truck drivers.

Work investigated long-haul truck drivers next. A climate scale specifically for trucking was developed and this customized approach help show that the scale worked and suggested that safety climate was a normative behavior frame of reference for long-haul truck drivers (Huang 2013). Since safety climate had significant influence from supervisors, Huang and the team examined the links between both supervisor's and driver's understanding of safety climate (Huang 2014). The research showed that supervisors' perceptions of safety climate had no influence on drivers' safety behavior, though drivers' perceptions of safety climate predicted their own safety behavior (Huang 2014). This was important because it showed evidence that supervisors were not influencing safety behavior, but that drivers did have a safety climate. The isolation drivers experienced as lone-workers had apparently severed the safety climate link with their supervisors, yet their own disconnected safety climate existed. This was very interesting as past research had shown connection to management as an important dimension in safety climate (Zohar 1980, Brown 1986, Dedobbeleer 1991, Wallace 2006). This work also showed that future research needed to focus on the drivers and their work environment. This work was also completed before 2015, which became very important in long-haul truck driver safety.

Before safety research is further reviewed another perspective must be brought in. Long-haul truck driving has been a popular theme in America for many years. The song "Convoy" is a story of a trucking convoy that topped music charts in the 1970's. Part of

the song lyrics included, “Swindle sheets,” which is slang for logbooks (Ochs 2017). As part of regulations most long-haul truck drivers must maintain records of their driving called records of duty status (RODS). These records include off-duty and on-duty time that is regulated by time limits (Hours of Service of Drivers 2021). Drivers have 11-hours of total driving time each day and a 14-hour window to operate in, after which a minimum 10-hour break must be taken, among other rules (Hours of Service of Drivers 2021). Records of driving time were kept manually by drivers in written log books, which could easily be adjusted to allow the driver to drive beyond regulated hours. This practice of adjusting logbooks was so common it was documented in the song “Convoy”. The practice was also a concern of the US Government. In 2008 there was a regulation review to understand how to improve driver rest. The results could not determine if circadian disruption or recovery time was the better approach to reduce fatigue (Federal Register, 2008). This supported how difficult it was to guarantee drivers were getting sufficient rest between driving cycles, a consequence of being long-workers drivers do not have regular supervision.

Today long-haul truck drivers use automated systems to log data and transmit their RODS called an electronic logging device (ELD). An ELD is a system that digitally records and transmits driving metrics. It, “Synchronizes with a vehicle’s engine to automatically record a driver’s off-duty and on-duty time and securely transfer HOS [hours of service] data to a safety official,” (FMCSA). The implementation of the ELD system was intended to improve both driver economy and road safety. The expectation was that by automating HOS and RODS data logging it would remove a time burden on drivers, and an automated system would eliminate both accidental and deliberate HOS

mistakes (Federal Register 2015). This meant that drivers would have mandatory rest time between their on-duty status that could not be avoided or swindled away. The ELD mandate was phased in for engines made in the year 2000 or later (FMCSA). Each phase was two years so that drivers and carriers could make adjustments and implement the changes. The first phase started in 2015 and the full compliance was established at the end of 2019 (FMCSA).

The implementation of the ELD system created a unique and valuable opportunity for safety research. The insertion of technology that constantly monitored drivers was new and had the potential to change safety climate and safety culture because the ELD created a new working environment for drivers. This opened up possibilities that the ELD might serve as a proxy for a supervisor and create a new safety climate dimension or change driver's practices or beliefs and thus shift their safety culture. Since it has already been established that safety climate could be captured by a customized survey, novel research needed to dig deeper. One area was to evaluate safety culture of long-haul truck-drivers and examine how the ELD system changed their common beliefs, attitudes, practices, values, and behaviors. This work would need to be performed in their work environment, truck stops for example. The research methods could come from past examples such as interviews, focus groups, or audits. If successful this research would help understand if a safety culture could be identified in lone-workers such as long-haul truck drivers, if the ELD system influenced their safety behaviors, and if links exist in lone-worker between safety culture, safety influences, safety climate, and safety outcomes.

PAPER

I. EARLY OUTCOMES OF THE ELD SYSTEM IN THE TRUCKING INDUSTRY

Carlton Washburn, Susan Murray, Ph.D., and Clair Kueny, Ph.D.

Missouri University of Science and Technology,
1201 N. State St., Rolla, MO USA 65409

ABSTRACT

In the Federal Register (December 16th, 2015), the Federal Motor Carrier Safety Administration (FMCSA), part of the Department of Transportation (DOT), outlined new regulations for electronic logging devices (ELDs) used in the truck driving industry, with the goal of improving highway safety. This paper explains what an ELD is, and what it was expected to provide to truck drivers, their companies, and regulators. Today the ELD regulations are fully phased in, and through interviews with truck drivers we examine the problems they experienced prior to, during, and after ELD implementation. Finally we examine how effective ELDs were on trucking safety from both drivers and trucking crash data.

1. INTRODUCTION

1.1. HISTORY OF TRUCKING SAFETY

Truck driving safety has been tied to government regulations since 1937, when the first hours of service laws (HOS) were established (FMCSA). The rules outlined limits for drivers to improve safety. The main aspects of driving addressed over the years were the driving time, duty time, off-duty time, and at what point the overall window resets (FMCSA). Significant modern changes to the HOS laws started in 2003. From 2003 to 2008 several changes were made, such as requiring drivers to be off-duty for 10 hours instead of eight, requiring a 34 hour break before a driver could start driving again, and setting a 14-hour duty period that was not extendable meaning that drivers had to complete all driving for a day within a strict 14 hour window (FMCSA). The next major shift from the FMCSA came in 2015, when electronic logging devices were required in phases. There were three phases, spanning from December 2015 to December 2019, which started with awareness and ended with full compliance (Federal Register, 2015).

The continuous growth in regulations was a result of complex factors that affected safety, including the increased use of the US highway system, improved vehicle technology, and industry growth. These factors can be measured directly. The increased usage of roads can be measured by vehicle frequency. The speed of trucks on highways can also be captured. The volume of trucks, number of companies, and goods hauled can all be captured. These can then be correlated to trends in crashes and fatalities, to understand if a change in regulations make the trucking industry safer.

There are other influences on trucking safety that are harder to measure. For example, how can the fatigue of a driver be captured? Measuring fatigue is difficult; it is influenced by many factors (i.e. sleep quality, sleep debt, medications) and can affect people in different ways (Murray & Thimgan, 2016). Researchers can measure the lingering effects of tiredness indirectly by monitoring performance. The differences among people and how they recharge make it more of a challenge to determine what the proper rest time and process should be. This concern was a focus during the 2008 regulation review, and it was determined that there was no conclusive data on whether circadian disruption or recovery time was the better approach to reduce fatigue (Federal Register, 2008). This shows how difficult it can be to determine both a safety system and supporting regulations that provide effective results across diverse types of people and driving situations.

2. WHAT IS AN ELD?

Commercial motor vehicles (CMVs) are tracked via driving logs. This allows drivers, companies, and regulators to monitor the hours and distance a driver has traveled. These logs are formally called records of duty status (RODS) by the Federal Motor Carrier Safety Administration (FMCSA). In the past, drivers would maintain their RODS in handwritten books. The recent shift to a digital record has progressed through a few systems, with the electronic logging device (ELD) being the current federally mandated system for CMVs.

An ELD is a digital system to track driving metrics. Specifically, it "Synchronizes with a vehicle's engine to automatically record a driver's off-duty and on-duty time and securely transfer HOS data to a safety official" (FMCSA). The ELD connects to the engine control module in the truck and is either a hardwired system in the truck or a wireless system connected to a smartphone. Regardless of how the system integrates to the truck, the system tracks six metrics (listed below), which together comprise RODS.

- Engine power status
- Vehicle motion status
- Miles driven
- Engine hours
- Identification of driver/authorized user, vehicle, and motor carrier
- Duty status

There were four main rules associated with the ELD implementation. The ELD system was intended to help drivers and their companies comply with these rules to insure a driver has regular opportunity to rest, avoiding fatigue and increasing alertness. There are the 14-hour, 11-hour, 30-min break, and 60/70-hour rules (FMCSA). The first three rules nest in one another. Once a driver starts driving for the day, a 14-hour clock starts and the driver cannot exceed this until the driver has taken 10 consecutive hours off duty (i.e., they have to have at least a 10 hour rest period before starting their next 14-hour clock). The 11-hour rule falls within the 14-hour rule and says that a driver can only drive 11 of the 14 hours. Within the first 8 hours of the 11-hour rule, a drive must take at least one 30-minute break. The 60/70-hour limit depends on if the driver operates every

day of the week or not, as a driver is limited to the total hours in their cycle. In a 7-day or 8-day cycle, depending on the driver's work schedule, the driver may not drive after 60-hour or 70-hours, respectively. The weekly drive cycle resets once a driver takes 34 consecutive hours off.

The use of ELDs was phased in, and focused on engines manufactured in 2000 or later, with some exceptions (FMCSA). The three phases helped align the trucking industry to a single ELD system (FMCSA). Each phase shown below lasted two years, providing time for the industry to adapt to the changes.

1. December 16, 2015 – Awareness and Transition Phase
2. December 18, 2017 – Phase in Compliance
3. December 16, 2019 – Full Compliance

There were exemptions provided, with four specific exemptions of pre-2000 vehicles, tow-away drivers, drivers who do not need to maintain RODS, and drivers who maintain logs for less than eight days in a 30-day cycle. They helped provide a framework that supported truck drivers and companies moving goods over distances for commercial needs, while maintaining flexibility for other truck drivers. For example, farmers hauling grain from the field to storage were exempt since they have short times when they harvest. In contrast, hauling grain from an elevator to a processing plant may require driving several miles and is for commercial use.

3. WHAT WAS ELD EXPECTED TO DO?

By implementing the ELD system, the expectation was to improve economy and driver safety. The logic was that by making data logging both easier and more accurate, both trucking companies and authorities could have precise data on the hours of service (HOS) and RODS information during stops, such as during weight station inspections. Digital records would remove a paperwork burden from drivers, as it would be automatically tracked and easy to read by authorities. The expectation was that this electronic system would also avoid both deliberate and accidental HOS mistakes (Federal Register, 2015).

It is unclear whether the ELD system resulted in improved driver safety. In 2014 the FMCSA funded a study to see if ELD systems improved safety. The study found an improvement in decreasing HOS violations and an 11.7% crash rate reduction. However, the small sample size made it difficult to understand the results with respect to fatigue as a contributing factor in driving accidents (Federal Register, 2014). This difficulty tied into the challenges in measuring fatigue noted in the 2008 review and underscored the complexity of effective safety systems. The 2014 work showed that further study was needed to understand how the ELD system affects driving safety.

Measuring the outcomes of a safety system is difficult. The quantity of data was cited as a limitation, and it is possible that larger studies might help. We believe that considering the complexity of commercial motor vehicles, a study that considers safety in more depth would be useful. As such, we present research that takes a deeper dive (through thorough qualitative data collections and analyses) into how safety regulations,

systems, and specifically the ELD system affects drivers. To accomplish this goal, truck drivers themselves were involved. The research included 40 semi-structured interviews with truck drivers, with the majority conducted at truck stops. Quotes and common themes of the conversations were captured, to help understand how the ELD system affected the drivers.

4. RESEARCH METHODOLOGY

To better understand the effects of the ELD system on drivers, the first author conducted a series of semi-structured interviews with truck drivers. After obtaining institutional review board (IRB) approval for the research, truck drivers were approached at a Loves truck-stop in Missouri and offered a $10 gift card in exchange for completing a permission form, demographic survey, and answering interview questions. Each interview took approximately 10 minutes, and answers were written down since the background noise of the truck stop caused audio recording issues.

In total, 40 truck drivers indicated agreement to participate and were interviewed. Of the 40, 39 of the drivers were male and one was female. Participants spanned 32 different trucking companies, and the drivers were from 17 states. The majority drove Class A trucks, with one driver licensed for Class E, and another was licensed for a CDL flatbed. Ages ranged from 23 to 68 years old, and driver experience ranged from 3 days to 40 years.

The interviews started with the same set of questions and example interview questions are provided below. Each driver was asked every question and follow up

questions as needed to gain additional information around how the ELD system was changing their behaviors, and what was motivating them as drivers. At 25 interviews it appeared we had reached data saturation, where the same answers were being captured; however we gathered an additional 15 (reaching a total of 40 interviews) to ensure a variety of driving experiences were captured in the data. At this point the research concluded.

Example interview questions

- How has the ELD system changed your driving habits?
- Do you feel the ELD system has changed driving safety?
- What would motivate you to be safer?
- What would make you feel safer as a driver?

5. PROBLEMS PRIOR TO ELD REGULATIONS

This researched helped to uncover both common patterns many of the drivers experienced, and a few extreme situations that showed the spectrum of pressures and decisions a driver may face because of structures embedded in the ELD system. For example, eleven drivers stated that the ELD system prevented them from engaging in illegal behavior, such as keeping multiple logbooks or driving longer due to company pressure, a practice referred to as “pushing” the driver. One driver with 10 years of Class A experience stated, “When I ran paper [logs], I ran three logs." He continued to explain that paper-logs required him to write, and this slowed things down. Other interviews commented on using multiple logs so that HOS could be lengthened so they could make

more income by driving longer. A different driver with over 19 years of Class A experience made a comment that summarized many of the interviews. “Before the ELD I drove how I wanted. I could stretch an hour. The ELD helps me get more rest." Habits like the example of driving beyond the HOS laws were commented on by several drivers. One expectation of the ELD mandate was to eliminate this tendency, and the interviews supported the FMCSA expectation.

Both of these drivers’ comments above also touch on another expectation of the ELD system. Rest, alertness, and fatigue all surfaced in the interviews. For example, a relatively new driver thought that the ELD system kept him safe by not allowing him to drive for more than 11 hours. Another with 15 years of experience made a similar comment, “It's stopped guys driving over hours." Yet another expanded on why, "ELD stops the dispatcher from driving you." This driver went on to explain that that dispatchers were motivated by moving product and less concerned about the distance and time it took to drive. Our research suggested that the motivation of a driver along with their relationship with their company can create a culture of bypassing regulations.

A key part of understanding how a safety system affects a driver also includes the relationship with the company they work for, in addition to the regulator rules. This is because the alignment between the driver, company, and regulations is important. If a driver faces a conflict between driving longer to make more money, and this is supported by their company who also benefits, the consequences that regulations enforce may not be sufficient to align behavior. For example, a veteran driver with over 40 years of experience made the comment, “The company wants the drivers to be alert and ready to work when they start their day. Being alert and having good depth perception makes a

good truck driver." However, this veteran driver went on to explain that before the ELD system, there was a big difference between what companies said and what was expected. When asked for an example prior to the implementation of the ELD system, he stated, "Decatur [Illinois] to LA in two days was a common expectation." A Google Maps query shows this is a 29 to 30-hour drive across 1,943 to 2,026 miles, depending on the route. He concluded by explaining that ELD and GPS technology had helped align what companies say and their expectations.

In addition to company pressures prior to ELD implementation, drivers had other motives for extending their driving hours and pushing themselves. Specifically, during the interviews, the majority of the drivers stated they were motived by money. In one extreme example a driver provided insight into how much influence this had on his driving habits. He had 15 years of driving experience and explained that if a driver could get one more load in, it could be another $300 or $400 in their paycheck. He stated that (prior to ELD implementation) he drove three or four days without sleep, so he could get more loads in. The caffeine pills that enabled his driving binge caused an enlarged heart and three hospital visits. These hospital visits were expensive, and they took the driver away from driving while he recovered. As a result, he lost his house due to the consequence of excessive driving. This is an extreme example and outlines how motivated drivers can be to earn extra money, especially without clear regulations in place to help discourage such behavior.

6. DID ELD REQUIREMENTS WORK?

The implementation of the ELD system was intended to both improve safety on the roads and the economy of the trucking industry. Part of our research was to dig deep and get beneath generalizations, into the specifics of what was really motivating driver's behavior. Some drivers told a very different story about what happened as the ELD system phased in, not as positive as the comments referenced so far. Several drivers explained that their top speed is limited. So, to make up time lost from loading, bad weather, or other complications they would speed through construction zones and small towns. A driver with 20 years of experience and who was hauling rolls of paper summarized by saying, "The old system a driver could stop the clock and sleep when needed, and then re-start it. With the ELD a driver has to drive." Drivers from four to 30 years of experience reported that they avoided eating and resting, so they could keep up with the ELD clock. The pressure created by having a clock count down was influencing the drivers. As a result, they were driving sick, and distracted by hunger.

There were two indications on why there was this shift in behavior with the implementation of the ELD clock. The first factor was pay. With the ELD system, drivers could no longer extend their driving arbitrarily. Once they started driving their ability to earn money was controlled by a clock not them, and that time was very precious. One driver explained he was overloaded and needed to return to have some freight removed. His 14 hours had already started, and so he would need to rush to complete that day's delivery, to account for the lost time having to return part of his load. Other more seasoned drivers that drove before the ELD implementation explained their

income had been reduced after the ELD system, in large part because they could no longer “run outlaw”, explained as keeping multiple logs.

The second indication of the behavior shift was more complex. Drivers talked about watching the ELD clock run down and feeling like they were being treated like robots. They also talked about getting stuck in weather and traffic, things that are hard to predict and plan for. As an example, a driver with 15 years of experience hauling fuel reported that he drove faster because of the ELD system, because he had to rush due to a 15-min delay due to traffic, “There is no lee-way, no flexibility.” The inflexibility of the clock impacted truck drivers in other ways. Truck drivers reported having difficulty in finding open slots in truck stops or having to shut down in unsafe areas. The result was that drivers would push to keep up with the clock, which was always counting down, to compensate for future events or delays. The drivers felt they could no longer pull over or make professional judgments on the best way to address challenges.

Several drivers commented that they thought crashes had increased due to ELDs. A driver with eight years driving a Kenworth truck stated, "There were more crashes since it [ELD] went into effect." It is important to understand the observations the truck drivers were making, to see if there is a correlation between the implementation of the ELD system and chances in trucking crashes. Such correlations between qualitative and quantitative data can help to understand the relationship between changing regulations and the diverse people and driving situations that are affected by the changes.

To understand these comments, and gain insight into the relationships, we extracted data from the National Highway Traffic Safety Administration’s (NHTSA) Fatality Analysis Reporting System (FARS) database to make a quantitative comparison

with the truck drivers' observations. Three charts were prepared showing the crash rate per 100,000 large trucks, the total number of large truck crashes, and the large truck crash rate per 100 million miles traveled. Since the ELD system started to phase in in 2015, we pulled data starting with the year just before ELD phase-in (2014).

The raw number of large truck crashes in Figure 1 showed a steady increase each year. This data showed that crashes are increasing but does not account for any changes in the number of vehicles on the road, or the quantity of miles driven. It is a raw trend that needs normalization to put the trend into context, so it can be better understood.

The rate per 100K registered trucks normalizes the data to the number of trucks each year and shows an initial increase and then decrease (about two years after ELD phase-in started) in Figure 2 resulting in a curvilinear relationship. This trend is more helpful, as it accounts for the changes in registered trucks. If the number of registered trucks increase or decrease, a reorganization of the crash data is needed to understand this relationship. However, it does not consider if the truck are being driven or not, only if they are registered.

The rate per 100M miles driven shows an increase and then leveling off in Figure 3, showing an asymptotic shape. The data presented in Figure 3 normalizes the data to trucks activity on the road and is the most helpful perspective. This normalization accounts for the trucks being driven and is closely related to HOS concept introduced earlier. The trend also aligns with the observations of the truck drivers who reported an increase in crashes.

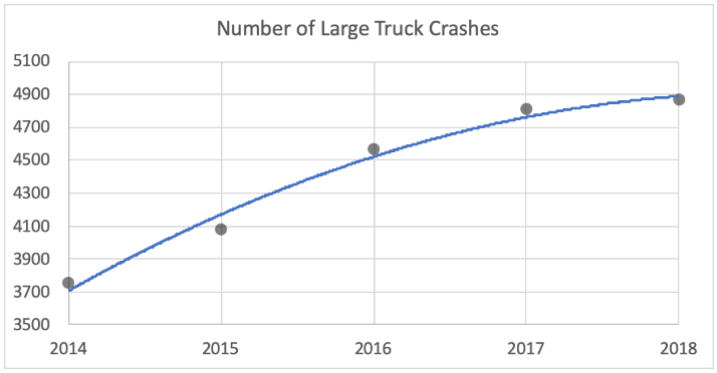

Figure 1. Total number of large truck crashes (NHTSA FARS Encyclopedia)

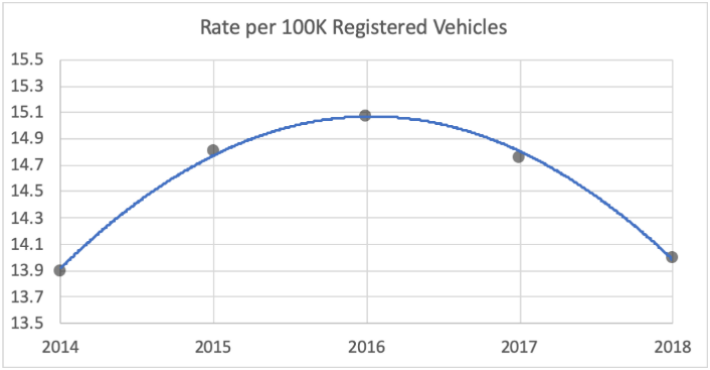

Figure 2. Crash rate per 100K Registered Trucks (NHTSA FARS Encyclopedia)

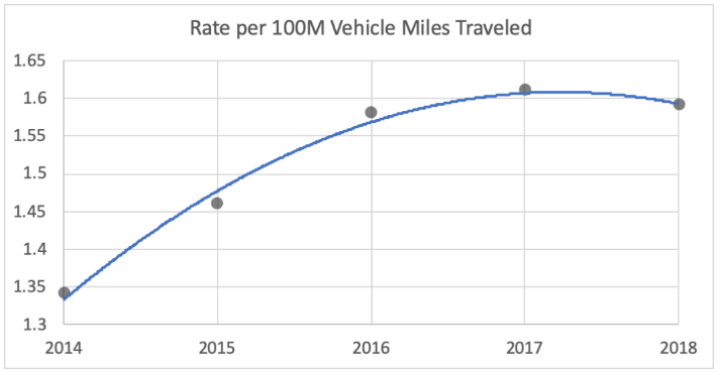

Figure 3. Crash rate per 100M miles driven by large trucks (NHTSA FARS Encyclopedia)

7. CONCLUSIONS

The ELD system brought an overdue solution to pressure being placed on drivers to alter their records and drive longer than was safe. It also eased the burden of paperwork and provides more accurate data on the trucking industry. However, the ELD system is a rigid system and this is causing drivers to report concerns. The ever present clock counting down, and knowledge that a storm or traffic jam might slow them down is causing some drivers to report they are compensating in unsafe ways. The inability to cheat the system is adding pressure to drivers to make what money they can in the time they are given. Looking beyond the comments of the drivers to crash data, crashes have increased during the beginning of the ELD implementation and appears to be leveling off. Full ELD compliance was still a year away from when the crash data were available, meaning the correlation between ELD and crashes cannot be fully understood. Though this data is early in the ELD implementation, there is an indication that a balance between rigid rules and flexibility of human judgment needs to be struck to maximize safety in the trucking industry.

REFERENCES

About ELDs Improving Safety Through Technology. ELD. https://eld.fmcsa.dot.gov/About.

Administration, N. H. T. S. *FARS Encyclopedia*. FARS Encyclopedia: Trends - General. https://www-fars.nhtsa.dot.gov/Trends/TrendsGeneral.aspx.

Driver's Records of Duty (RODs) and Supporting Documentation. A&I online - Motor Carrier Analysis and Information Resources Online. https://ai.fmcsa.dot.gov/NewEntrant/MC/Content.aspx?nav=Logs.

ELD Fact Sheet. FMCSA. https://www.fmcsa.dot.gov/hours-service/elds/eld-fact-sheet.

Electronic Logging Device (ELD) Exemptions, Waivers and Vendor Malfunction Extensions. FMCSA. https://www.fmcsa.dot.gov/hours-service/elds/electronic-logging-device-eld-exemptions-and-waivers.

Federal Register. (2008, November 19). *Federal Register Vol. 73, No.224*. https://www.govinfo.gov/content/pkg/FR-2008-11-19/pdf/FR-2008-11-19.pdf

Federal Register. (2014, May 12). *Federal Register Vol. 79, No.91*. https://www.govinfo.gov/content/pkg/FR-2014-05-12/pdf/2014-10813.pdf

Federal Register. (2015, December 16). *Federal Register Vol. 80, No.241*. https://www.govinfo.gov/content/pkg/FR-2015-12-16/pdf/FR-2015-12-16.pdf

Hours of Service History and Overview. https://www.fmcsa.dot.gov/advisory-committees/mcsac/hours-service-history-and-overview.

Murray, S., & Thimgan, M. (2016). *Human fatigue risk management - improving safety in the chemical processing*. Elsevier Science Publishing.

Summary of Hours of Service Regulations. FMCSA. https://www.fmcsa.dot.gov/regulations/hours-service/summary-hours-service-regulations.

II. ESTABLISHING LINKS BETWEEN SAFETY CULTURE, CLIMATE, BEHAVIORS, AND OUTCOMES OF LONG-HAUL TRUCK DRIVERS

Carlton Washburn, Clair Kueny, Ph.D., and Susan Murray, Ph.D.

Missouri University of Science and Technology
1870 Miner Circle., Rolla, MO USA 65409

ABSTRACT

This paper examines the safety relationships between safety culture, safety influences, safety climate, and safety outcomes for long-haul truck drivers. The relationships focus on the intersection of the electronic logging device (ELD) technology, regulations, and truck drivers that fall into the lone-worker category. Through research questions links between safety culture and safety climate were established with links between the layers. The implementation of the ELD system was associated with safety outcomes.

Keywords: Safety, Culture, Climate, Lone-Workers, Truck Drivers, Trucking

1. INTRODUCTION

This paper is part of research to understand the connection between safety culture, safety climate, and safety behaviors. This study examines the factors of positive and negative influence, and the effect on safety behaviors in lone-workers, specifically long-haul drivers in the truck driving industry. Specifically, we focus on the effects of

implementing electronic logging devices (ELDs) on truck driving safety behaviors that were phased in starting in 2015 [1]. ELDs replaced hand-written logbooks of driving metrics with a computerized system. This paper explores the intersection of the ELD technology, regulations, and truck drivers.

While efforts to improve safety in industrial settings have improved the working environment both reducing hazards and improving quality of life; accidents, injuries, and loss of life still occur. These deaths and injuries are not evenly distributed, rather the majority as reported by the Bureau of Labor Statistics continue to be transportation incidents. In 2019 there were 2,122 fatalities due to transportation incidents [2]. There are many reasons for transportation to top the major categories list compared to other workplace sectors. One reason is that transportation workers are removed from many of the engineering controls and safety systems common in the workplace. For example, they are alone without direct supervision, there are no structured checklists or signoffs, they do not use workstations designed to relieve stress, and they lack processes such as lockout-tagout. There is a level of autonomy workers have when driving, and increased opportunities to make their own decisions. Autonomy of drivers increase when they are independent and away from supervision shifting them to lone-workers. Lone-workers will be defined in more detail in the background section of this paper, in general they are workers that perform their work away from others and without supervision. Another reason transportation incidents are the highest cause of fatal injuries is that there are many more variables in play outside the four-walls of an office or factory; the open road is both an uncontrolled environment and a constantly changing environment.

Studying such uncontrolled environments is difficult. Some variables that affect truck drivers can be measured directly such as time driving, speed, and location. Other variables are harder to capture such as how decisions are made by drivers, driver influences, and behaviors are impacted by positive and negative reinforcements. As difficult as these variables are to capture, they are important and interesting. For example, how does the safety outcome change if we adjust reinforcement mechanisms linked to drivers' safety influences? To understand this question, it is first necessary to understand potential links between influence, safety climate, and safety outcomes. For lone-workers like truck drivers, these links might be different or may not exist at all due to the workers seeming independence from their organization. For this paper, interviews were conducted and resulting data were analyzed and compared to trucking crashes as measured by National Highway Traffic Safety Administration's (NHTSA) Fatality Analysis Reporting System (FARS) with the goal of identifying trends in perceptions of organizational safety culture and possible connections to lone-worker safety behaviors.

2. BACKGROUND OF SAFETY CLIMATE AND CULTURE

Both safety climate and culture have been used in research for years. Safety climate research has existed for decades, and many point to Zohar's work in the early 1980s as the beginning of a new chapter in our knowledge, as his research proposed that there was a measurable connection between climate and organizational patterns in an organization [3]. This connection meant that researchers could study and develop models of how climate and behavior were connected. A few years later the concept of a safety

culture started to become common after the report on the Chernobyl Reactor Incident by the International Atomic Energy Agency was released [4].

Over the next two decades the research community delved into the relationships between climate, culture, and safety. As research progressed, confusion mounted. Researchers used the phrase "safety culture" to cover a broad mix of human factors, psychology, and safety engineering research. The concept of safety culture became very broad, to the point of ineffectiveness [5]. Safety culture and safety climate were often substituted for each other, muddling research outcomes. To reduce confusion, research efforts shifted focus to defining these safety concepts [6,7,8,9].

By the late 1990s a separation of safety climate and safety culture started to emerge. This came in part from how research was performed. The main tool for many researchers was survey instruments, and it was determined that surveys can only reach the surface of participant's perceptions and attitudes [10]. This realization helped to bring separation between safety climate and safety culture. Climate can be considered directly observable by the outside world, and it has generally been accepted as shared perceptions of an organization's policies, procedures, and practices [3,11,12]. Climate was further defined by its dimensions. Zohar's 1980 work on safety climate defined eight dimensions that include management's commitment, open and frequent communication between workers and supervisors, and both controls and good housekeeping in plants. Safety climate dimensions were reduced to three in subsequent work and focused on management concern, management action, and physical risks [13]. Later work further reduced safety climate dimensions to two, management's commitment to safety and worker's involvement in safety activities [14]. Though the specific

dimensions of a safety climate vary in both their definition and how broad they are, a common theme was the value that management placed on safety in the workplace. For lone-workers who lack regular access to management, the question remained if there was a link between supervisors and work safety or if something else influenced their safety behaviors?

With the definition of safety climate coming into focus, a safety culture still needed to be defined. In contrast to climate, culture was defined as not quickly interpreted by outsiders and as a set of common beliefs, attitudes, practices, values, and behavior patterns among a group of people [15,16,17,18]. Part of this separation included that climate is what happens, whereas culture is why it happens. Though safety culture definition lacks the depth of research that safety climate has received, it's generally accepted that safety culture is the influencing mechanism for safety climates and ultimately safety behavior [19,20].

Surveys continued to be the mechanism for safety climate and culture research. Many safety researchers build on Zohar's work surveying over 400 employees across twenty industrial organizations in Israel [3]. The pattern of using surveys to capture safety climate and/or culture continued [21,22,23,24,25,26]. Including research into the safety of truck drivers [27,28]. However, surveys as a tool have a limited capability to reach into safety climate, let alone culture [29]. If research is to move beyond climate and into culture, additional tools are needed, particularly with respect to understanding safety culture influence among lone-workers.

Notably, recent work has started to look at lone-workers, following a trend of becoming more specific in the types of workers safety research has focused on. There is

not a specific definition that covers all lone-workers, rather a loose understanding that lone-workers perform their jobs away from others in their industry, often in isolation, and often without access to supervision [30,31,32,33]. Workers that are commonly grouped as lone-workers include traveling nurses, airline workers, telecommuters, and truck drivers. Lone-workers such as truck drivers can be difficult to research due to access. This means research needs to go outside the organization of the trucking companies and to the drivers while they are working. This is important because people are the center of the research, they are the laboratory [34].

To understand the connection between safety culture and safety behaviors among lone-worker truck drivers, research needed to dig deeper. For example, the early 2000s marked a transition to safety climate research into truck drivers. Early work tried to create a link between safety climate and management by analyzing accidents [35]. The assumption was that a stronger safety climate would reduce accidents. However, there was no evidence of this relationship, and the authors pointed out that people are reluctant to acknowledge their responsibility in an accident which may have biased their survey results [35,36]. However, considering how many truck drivers are in fact lone-workers and lack many of the features common to a safety climate, like management involvement [14], this may explain why past research was unable to find a clear relationship between safety climate and safety behaviors.

Further research looked specifically at links between safety climate and driving behaviors for short-haul drivers. The first used a climate scale with six safety dimensions and four aspects of self-reported driving outcomes [37]. The research showed that their safety climate scale predicted behaviors including driver error, traffic violations, and

driver distractions [37]. The second study tried to establish a link between drivers and management [38]. The work showed strong evidence that the higher the perceptions management, the higher the safety climate would be, and accidents would be reduced [38]. In this study the drivers and management had daily interactions. As the decade progressed safety climate for drivers was combined with fatigue, occupational stress, and near misses [39]. Similar to Wills et. al. (2006), a relationship between safety climate and occupational stress was established with fatigue-related crashes by Strahan et.al. (2008). However, as noted, all three studies looked at short-haul drivers who had daily contact with their colleagues and supervisors. Thus, arguably, these short-haul drivers are not necessarily lone-workers as they have frequent access to supervision. Supervisors can reinforce company safety systems and provide regular access to safety mechanisms strategies like checklists, signoffs, etc. However, even though this research did not explore long-haul drivers that would be grouped with lone-workers, this work was encouraging, as links were at least established between safety climate features and safety behaviors among truck drivers.

The next phase of studies delved into long-haul trucking. Researchers first tested a climate scale developed specifically for trucking companies [18]. The results found the scale valid and suggested that safety climate served as a normative behavior frame of reference for long-haul truck drivers. Thus, the findings suggested that the work environment was material to understanding the safety climate of lone-workers. However, Huang, et. al. (2013) completed their research prior to ELD implementation and the scale included aspects that have become obsolete. ELDs replaced hand-written logbooks of driving time and other metrics with a computerized system that started phasing in during

2015. For example, the survey question, “Will overlook log discrepancies if I deliver on time,” does not align with an ELD system that automatically logs information. Next, Huang and the team turned their attention from testing a climate scale to testing the relationship between supervisor’s and driver’s understanding of safety climate [28]. They gained insights into how the supervisor’s views of safety climate influenced driver’s safety behavior. Huang et. al.’s analysis indicated that the drivers’ perceptions of safety climate predicted their safety behavior, while supervisors’ perceptions of safety climate had no influence on drivers’ safety behavior [28]. This finding was critical because it indicated that supervisors were not influencing safety behavior. This was novel research compared to previous studies that connected management as a key dimension in safety climate [3,13,14,38]. Huang et. al.’s results broke the link of previously established dimensions of a safety climate, finding that the supervisors’ perceptions of safety climate had no link to drivers’ safety behavior. This also suggested that future research needs to focus on the drivers.

The previous climate scale established by Huang et. al. 2013 was used again and GPS data on deceleration (hard-braking) was also collected to study driving safety and hard-braking events [40]. This work examined the role of dispatchers in predicating drivers’ safety climate perceptions and hard-braking events. A more interesting outcome was that instead of increasing formalization to compensate for diminished control of supervisors, the data suggested that increasing driver’s autonomy, task meaning, and knowledge led to increased driver ownership of their own safety behaviors. Though only focused on survey results and six months of hard-braking data prior to ELD

implementation, it implies increased controls on drivers may result in less ownership and may result in unpredictable safety behavior.

Notably, though, as the aforementioned research was published, the trucking industry started to go through a radical change. From 2015 to 2019 a new system was phased in [1]. Traditionally long-haul trucks are tracked by driving logs written by the driver. This allows drivers, companies, and regulators to track the distance and hours of a truck driver. These logs are formally called records of duty status (RODS) by the Federal Motor Carrier Safety Administration (FMCSA) [41]. As technology advanced, regulations adapted and shifted to a digital records system. This system was called the electronic logging device (ELD). It started to phase in in 2015, and by 2019 was the federally mandated system for truck drivers.

An ELD is a digital system to track truck driving metrics. Specifically, it "Synchronizes with a vehicle's engine to automatically record a driver's off-duty and on-duty time and securely transfer HOS data to a safety official" [42]. The ELD connects to the engine control module in the truck and tracks metrics which together comprise RODS. The expectation of the ELD system was to improve both driving economy and driving safety. By using a digital system, the expectation was data logging would become more accurate and easier on drivers by removing a paperwork burden. It would also provide trucking companies and regulators with precise data that was easy to read and remove both accidental and deliberate errors. The last expectation was that the system would force compliance with driving time rules, and insure a driver has regular opportunities to rest. The regulations cover a 14-hour, 11-hour, 30-min break, and 60/70 hour rules that the ELD system monitors [43]. Once a driver starts their day, a clock

starts counting down from 14 hours. Within the first eight hours of driving they need to take a 30-minute break. Drivers have 11 hours of driving within the 14-hour time. Once their 14 hours ends a truck must stay stationary for 10 hours, allowing drivers to rest. Then the clock rests to another 14 hours and will start to count down once the truck move more than 5 miles per hour. The 5mph allows trucks to move among parking spaces if needed. The 60/70-hour rule depends on a driver's regular schedule. If a driver drives in a 7-day cycle they cannot drive after 60 hours, and if they drive on an 8-day cycle it's 70 hours. The weekly clock resets once the truck is stationary for 34 consecutive hours.

The implementation of the ELD system changed the dynamic of long-haul trucking and may have altered the influences drivers experience in regard to safety. Pressures from their supervisors to drive longer, to maintain multiple logbooks, and to push themselves to complete a delivery all changed. A system was constantly monitoring aspects of their driving performance, with a clock constantly counting down. This raised several questions around the safety influences on a driver, a driver's perception of safety in regard to these new rules and processes, and safety behavior changes the driver may exhibit.

The research questions explored in this study include:

RQ #1, Can a safety culture be identified among long-haul truck drivers, particularly considering their lone-worker status?

RQ #2, Given that long-haul truck drivers are classified as lone-workers, what influence does the ELD system have on their safety behaviors?

RQ #3, Do links exist between safety culture, safety influences, safety climate, and safety outcomes for long-haul truck drivers?

RQ #4, Since the ELD system is both a safety system and a proxy for supervision, did the implementation of the ELD system positively associate with safety outcomes?

3. MATERIALS AND METHODS

3.1. RESEARCH PROCESS

Until recently the main tool for research into safety behaviors has been surveys, and then applying the results to a climate scale. Surveys limit how deep an analysis can get and do not allow for probing questions that can illuminate understanding. To both reach an understanding of culture and to connect the links between culture and outcomes, semi-structured surveys were chosen as the research method for the current study.

Previous studies have started to link outcomes like hard breaking to climate perceptions but lacked insight into what needs to change to reduce hard breaking. To understand how to improve safety systems, deeper insights are needed. Schneider explained that people are the fundamental determinants of organizational behavior, and people and their settings are inseparable since people make the setting [34]. Researching lone-workers such as long-haul truck drivers meant that they need to be approached in their work setting.

After institutional review board (IRB) approval for the research was obtained, a series of semi-structured interviews were conducted through 2019 and early 2020 with long-haul truck drivers. The majority of the interviews were conducted at a truck stop in the Midwest. The process consisted of asking if a possible participant was a truck driver. If they were, then a $10 gift card was offered in exchange for completing a permission

form, demographic survey, and answering interview questions. Each one-on-one interview took approximately 10 minutes. The results were written down, as the ambient noise of the truck stop caused audio recording issues.

This approach was designed to access drivers in their lone-worker setting, and to provide the opportunity to delve into safety culture. By talking with drivers at a truck stop, it removed the influence of both supervisors and colleagues. The semi-structured interviews each started with the same set of open-ended questions around safety behaviors and what was motivating them as drivers. Then probing questions were added depending on how the participate answered. Examples of starting questions are shown in Table 1.

Table 1. Example interview questions

How has the ELD system changed your driving habits?
Do you feel the ELD system has changed driving safety?
What would motivate you to be safer?
What would make you feel safer as a driver?

The inclusion of the two ELD questions was designed to take advantage of a recent regulations change that phased in ELDs for truck drivers. The recent implementation of this system presented an opportunity to see how it affected driving safety behaviors and safety outcomes. It also provided a safety topic common to long-haul truck drivers that the interview could be structured around.

3.2. PARTICIPANTS

In total, 40 truck drivers agreed to participate, completed both a consent form and demographic survey form, and the interview. At 25 interviews it appeared data saturation had been reached, where the same answers were being captured. We gathered an additional 15 interviews to ensure a variety of driving experiences and diversity were captured in the data. After 40 interviews the research concluded.

The demographic survey spanned a variety of backgrounds and a partial representation of the data is shown in Table 2. The interviews covered 32 different trucking companies and drivers that filed taxes across 17 states. The majority of the drivers were licensed for Class A trucks, with one driver licensed for Class E, and another was licensed for a CDL flatbed. The ages of the drivers spanned 23 years old to 68 years. The experience ranged from 3 days of truck driving experience to 40 years. One driver was female, and the other 39 were male.

3.3. DATA ANALYSIS

Interview data were recorded in writing on-site during the interviews and then transcribed each evening into a database. Once all the interviews were complete the data were coded first by categories and then by themes, with alignment to the four research questions. Figure 1 shows a simplified schematic of how this was done. Each colored block in Figure 1 represents a piece of data. These data were responses to questions from the participants. Each interview was broken down into categories. This is shown in Figure 1 by the green, yellow, and blue data that aligned with a category. Then the categories were analyzed for themes as shown in Figure 1 by both the groupings of the

colored blocks and the theme titles with asterisks. The themes were then used to see if they answered a research question. This is represented in Figure 1 by the grouping of the themes to the RQ's.

Table 2. Example of demographic data (N = 40)

	Mean	Min	Max	STD	Count	Percent
Age	45.5	23	68	13.4		
Years of experience	14.2	0.008	40	10.7		
Sex						
Men					39	98%
Women					1	2.5%
Type of truck are you licensed to drive						
Class A					38	95%
Class E					1	2.5%
CDL Flatbed Auto					1	2.5%
Level of education						
High school degree or equivalent					18	45%
Some college but no degree					12	30%
Bachelor Degree					5	13%
Associate degree					4	10%
Less than high school degree					1	2.5%
Ethnicity origin (or Race):						
White					27	68%
Black or African American					6	15%
Hispanic or Latino					3	7.5%
Other					2	5%
Native American or American Indian					1	2.5%
Asian / Pacific Islander					1	2.5%
Tobacco use						
None					25	63%
Multiple time a day					13	33%
Once a week					1	3%
Alcohol use						
Once a month					18	45%
None					15	38%
Once a week					5	13%
Once a day					1	2.5%
Twice a year					1	2.5%
Seatbelt use during off hours						
Always					30	75%
Sometimes					4	10%
Never					4	10%
Frequently					1	2.5%
N/A					1	2.5%

Note: Numerical data is shown as Mean, Minimum, Maximum, and Standard Deviation. Categorical data is shown as Count and Percentage.

To apply the method outlined in Figure 1 we will detail out the process for how RQ#1 was addressed. The categories came from the definitions detailed earlier in this

paper. For example, the definition of culture in the background section of this paper included a set of common beliefs, values, practices, and attitudes.

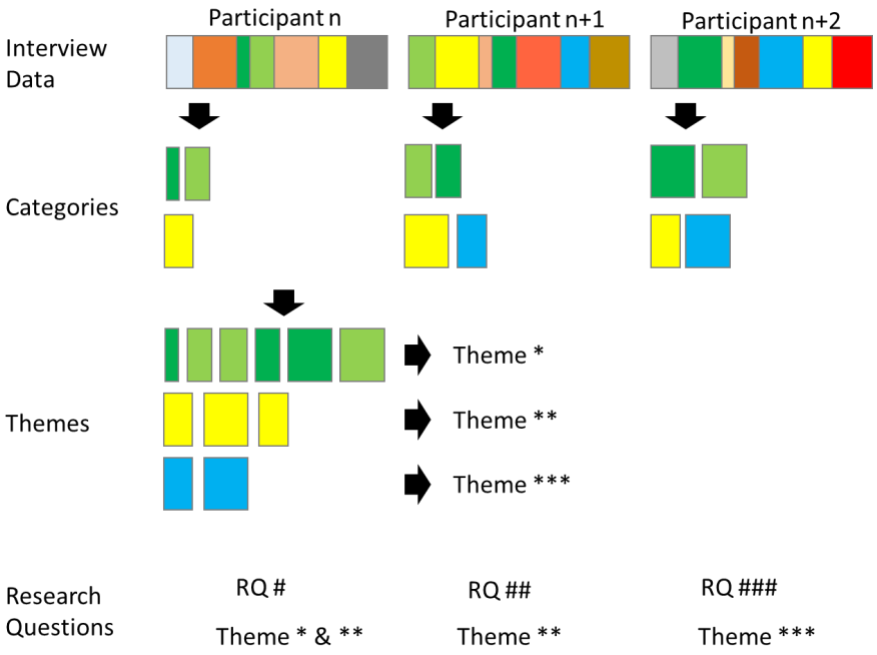

Figure 1. Data analysis method

To answer RQ #1, "Can a safety culture be identified among long-haul truck drivers, particularly considering their lone-worker status", the categories of Belief, Value, Practice, and Attitude were assigned to screen for culture signals. When analyzing the data APA definitions (see Table 3) of each category were screened against participant responses. As evidence supporting each category was found it was copied into the specific row in the spreadsheet. For example participant #2 explained that, "There are few rewards [incentives] other than the paycheck. If you do well, you get to keep running and have a job." Participant # 40 provided that he was motivated to use the ELD

because he could get a ticket if he is caught not using it and the ticket fee comes out of his pocket, and also counts against his insurance. Comments like these connected to a Belief that an unsafe behavior or complying with the ELD mandate would change how much money they would make were grouped.

As comments were coded in categories, the categories were then grouped together to form themes. These themes were then examined to understand what patterns were pervasive across the research. In the example above in the Belief category, one of the themes that emerged was Theme #3: Motivated by money. As themes emerged during the analysis they were color coded. This was done to make it easy to group and organize the themes across the rows in the spreadsheet.

Table 3. Research Question #1 Categories [44]

Categories for RQ #1	APA Definition
Belief	Acceptance of the truth, reality, or validity of something, particularly in the absence of substantiation.
Value	A moral, social, or aesthetic principle accepted by an individual or society as a guide to what is good, desirable, or important.
Practice	Performance of an act one or more times, with a view to its fixation or improvement; any performance of an act or behavior that leads to learning.
Attitude	A relatively enduring and general evaluation of an object, person, group, issue, or concept on a dimension ranging from negative to positive.

This analysis became the foundation for understanding if a research question was answered or not. The last step was to arrange the themes according to their support of each research question. The resulting coding structure of categories and themes can been

seen in Table 4. Some themes addressed more than one research question while others were only helpful in answering a single question. Some themes were left out because though they were interesting they did not support the research. For example there were practices of observable safety behaviors such as wearing safety vests around truck stops, wearing sturdy shoes, checking tires and couplings, and completing a 15-min pre-trip inspection. These supported a safety habits theme, but did not support a research question.

Table 4. Coding structure

Categories

RQ #1
- Belief
- Value
- Practice
- Attitude

RQ #2
- Complying with the ELD to stop and rest
- Adjustments to follow the ELD rules
- Compensating for the ELD driving limits
- Shifting driving times

Themes

RQ #1, Can a safety culture be identified among long-haul truck drivers, particularly considering their lone-worker status?

- Theme #1: Practice of following the un-written rules over the formal rules
- Theme #2: Valued human life
- Theme #3: Valued money
- Theme #4: Valued the law

RQ #2, Given that long-haul truck drivers are classified as lone-workers, what influence does the ELD system have on their safety behaviors?

- Theme #3: Valued money
- Theme #4: Valued the law
- Theme #5: Positive or negative attitude when evaluating the ELD system
- Theme #6: Shift to follow the rules and comply with the ELD
- Theme #7: Compensating for the ELD limits

RQ #3, Do links exist between safety culture, safety influences, safety climate, and safety outcomes for long-haul truck drivers?

- Synthesis of RQ #1 & RQ #2

RQ #4, Since the ELD system is both a safety system and a proxy for supervision, did the implementation of the ELD system positively associate with safety outcomes?

- 3rd party data from NHTSA FARS

4. RESULTS

RQ #1, Can a safety culture be identified among long-haul truck drivers, particularly considering their lone-worker status?

The first four themes addressed the first research question. As noted previously, safety culture was defined as not quickly interpreted by outsiders and as a set of common beliefs, attitudes, practices, values, and behavior patterns among a group of people. A practice, a value, and two beliefs were described by the participants.

Theme #1: Practice of following the un-written rules over the formal rules.

When participants were asked about driving safety, six participants that had been driving for years prior to ELD implementation described that pre-ELD companies expected drivers to follow un-written rules over the formal rules. Four of the drivers shared examples of keeping multiple log books to drive longer than was legal, the other two explained that the company rewarded driving longer than was allowed. This was a shared practice among the drivers, as they all provided similar descriptions and examples. This pre-ELD practice resulted in the drivers following the unwritten rules of driving longer than allowed, and breaking the formal rules. These comments provided insight into the safety culture shared among drivers before ELD implementation. The safety culture at this time prioritized driving time and not on safety practices such as rest since the practice was to follow the unwritten and less safe rules.

Theme #2: Valued human life.

The next theme that participants discussed was that they valued human life. Thirteen participants commented that they valued human life, and that it influenced their

decision to be safe when driving. Participants associated this value with their family, explaining that their family and other families were also on the road. They strived to be safe drivers to protect their family and other families.

Theme #3: Valued money.

The strongest feedback from the participants was how the value of money influenced them. There were 31 comments covering several perspectives, the most comments of all the themes. Some of the participants feared losing their job, others spoke of constraints on driving time and how it urged them to drive harder or rush to increase their paycheck, some commented on how fines or tickets would reduce their income. One driver made a direct comment, "If there is a money benefit, it can outweigh a safety risk." Participant 29 shared a concern around losing money by explaining that he was motivated to use the ELD because of the threat of a ticket which would make his insurance go up and cost him money. In all cases drivers valued money and this drove them to either comply with regulations or break laws depending how it might affect their income.

Theme #4: Valued the law.

Nine participants discussed how they valued the law. A sense of duty and standard of behavior were part of this theme. Whether drivers agreed with the ELD mandate or not, they respected the US Government and would abide by the law.

RQ #2, Given that long-haul truck drivers are classified as lone-workers, what influence does the ELD system have on their safety behaviors?

Five themes addressed RQ#2. Themes 3 and 4 from RQ #1 also addressed RQ #2, since they touched on the effects of the ELD implementation. Themes 6 and 7

contradicted each other. These opposing influences were both unexpected and interesting.

Theme #3: Valued money.

As mentioned previously, the strongest feedback from the participants was referenced to how they valued money and their safety behaviors seem most clearly motivated by money. There were 31 comments in total with several focused on the ELD system specifically. The participants expressed concerns about losing money through fines from violating the ELD limits and others contrasted this by talking of the restrictions the ELD system enacted that reduced their pay. For example one participant stated, “If you don't abide by the [ELD] laws, you get a ticket and they are expensive.” This driver was concerned about potential consequence to his paycheck if he was caught not using the ELD system. This was contrasted by two other drivers. One participant explained that the ELD system restricted driving time, and another elaborated that extra driving time meant one extra load, and this load could translate to $300 to $400 extra in a paycheck. Though the comments ranged from drivers fearing a pay reduction or losing their job to complaints about how the constraints in driving time affected their pay, ultimately there were all essentially motivated by money.

Theme #4: Valued the law.

This theme also supported both RQ #1 and RQ #2. When drivers were asked why they followed the ELD laws there was a theme of respect for the US government, whether they agreed with the law or not. One driver explained that though he didn’t like the ELD mandate he knew the FMCSA [Federal Motor Carrier Safety Administration] implemented the ELD system and he would follow the law because it was a federal rule

and mandated. Other driver's comments were similar and supported a standard of behavior and follow the ELD mandate because it's a US law.

Theme #5: Positive or negative attitudes when evaluating the ELD system.

This theme addresses attitudes from drivers when asked directly about the ELD system. This theme was interesting because some drivers would make both positive and negative evaluations of the ELD in the same interview. Positive evaluations included comments that the ELD kept the driver from being taken advantage of. One driver stated, "ELD stops the dispatcher from driving you." This presents an example before the ELD implementation when dispatchers would give drivers instructions regardless if they had exceeded their legal driving time for the day, and thus pushing him to drive. In contrast there were negative attitudes towards the ELD. Negative comments focused on the constraints of the ELD system and included that there was no time to relax because they were, "Pushing against the clock." The clock being the ELD countdown clock that tracked driver time. A more specific comment was, "You can't pull over to rest, 30 minutes is not enough." This driver was angry about how rigid the ELD system is, because the 30 minute break in the first eight hours of driving was insufficient. As part of these attitudes an emotional response was part of this theme. Anger and frustration from the negative attitudes and relief from the positive attitudes. These emotions are part of what separated this theme from others that were similar.

Theme #6: Shift to follow the rules and comply with the ELD.

There was a theme of the positive effect of the ELD system. Fifteen drivers made comments that they shifted their habits to follow the ELD rules. This was similar to both Theme #4 and Theme #5, but different because of what motivated the drivers. The

drivers spoke of how they appreciated mandated time off to rest and how that time to rest limited fatigue when they drove. They also spoke about no longer using multiple log books and "running outlaw" to comply with company expectations to complete deliveries illegally. One driver explained, "The ELD system helps you get rest. The ELD stops this [pressure to drive from his dispatcher] and stops driver fatigue." He continued to explain that the ELD helps drivers relax during breaks and this is safer because they can rest.

This was different than theme #4 which came from a sense of duty, and theme #5 that had strong positive and negative evaluations including emotions. This theme came from drivers shifting to follow the ELD rules because it benefited them and it was purely logical. They gained more time to rest by complying with the laws.

Theme #7: Compensating for the ELD limits.

One of the main purposes of the ELD system is to limit how much a driver can drive in a specific period of time and drivers spoke of the negative influence this had on them. Sixteen drivers commented on how they or others compensated for the ELD time limits. They spoke of speeding, rushing, driving while tired, and parking in unsafe areas. They were trying to make up for lost time since there was a limit on how long they could drive. They also discussed the consequence when the ELD system inconveniently ended their driving time. Drivers spoke about speeding with one commenting that the 30 min break caused him to drive 70 mph, to rush to a rest area. Several talked about the influence of the ELD clock. A driver explained he was compensating for lost driving time, "You can sit 8 or 9 hours to get loaded, with the [ELD] clock running. Then you get on the road and haul ass to get some money." Another commented, "Once the clock starts, it doesn't stop." With a similar comment describing the effect of the ELD clock,

"Drivers are continuously staring at it [ELD clock], it's constantly on their mind." One participant explained in detail the effect of compensating for the ELD clock, "Since most trucks have a speed limiter called a governor they can't speed on interstates and instead speed through small towns." The ELD clock was micro-managing the drivers to the point the clock was causing drivers apprehension and anxiety. The drivers were dreading the effect of the clock on their work.

RQ #3, Do links exist between safety culture, safety influences, safety climate, and safety outcomes for long-haul truck drivers?

To establish that links exist between safety culture and safety outcomes it was important to first establish that safety culture components (or layers) could be identified to address RQ #1 and RQ #2. There should also be clear relationships between the culture layers. These linkages should form a chain of understanding from what motivates a truck driver to their safety behaviors and safety outcomes. First, we will briefly summarize the themes from RQ #1 and RQ #2 and then examine possible relationships.

In RQ #1 layers of safety culture were identified supported by four different themes. Drivers provided stories following unwritten rules (i.e., practices) of driving longer than was legal, and prioritizing this over the formal rules around driving limits. Drivers also discussed how they valued human life, valued money, and valued the law. All three compelling them to be safer because of the consequences of unsafe driving. The themes provided insights into influences on their safety behaviors.

In RQ #2 drivers explained how the ELD system influenced their safety behaviors. The themes of valued money and valued the law from RQ #1 also supported RQ #2. Positive and negative attitudes were discussed in RQ #2 along with a shift to

comply with the ELD because it allowed drivers more time to rest. The attitudes and their associated emotions demonstrated aspects of a safety culture. There was also a behavior shift to compensate for the ELD limits. Drivers discussed unsafe behaviors such as rushing [speeding] and driving while tired. From drivers comments the ELD system has shifted their behaviors, in both positive and negative directions. These themes showed that the ELD system is particularly affecting driver's safety behavior, as lone-workers.

Two relationships were uncovered in this research. In the first relationship the participants described safety culture aspects in RQ#1 and then commented on negative safety influences in RQ#2. A clear link was described between valuing money and negative influence of the ELD system that led to drivers to compensate with unsafe behaviors such as rushing. In summary, valuing money linked to a negative ELD influence which connected to unsafe behaviors.

Another relationship found was the shift in the practice of using multiple log-books. Drivers reported moving from following unwritten rules to the practice of following regulations monitored by the ELD system such as driving time. Drivers made comments of getting more rest and driving less fatigued because of the ELD influence. The ELD system had consequences for both drivers and dispatchers and was a significant influence on safety behaviors. In both cases safety culture aspects of shifting to following regulations, influenced by the ELD system, linked to improved rest, tied to reduced fatigue, contributing to safer driving.

Self-reporting from the participants described conflicting results from the two relationships outlined above. The first relationship resulted in unsafe behaviors of

rushing from the influence of the ELD time limit. The second linkage resulted in more rested drivers from the regular time-off they have from complying with the ELD system. Moving beyond safety culture, this shared perception of policy and the practices of complying with the ELD system does align with the understood definition of a safety climate.

RQ #4, Since the ELD system is both a safety system and a proxy for supervision, did the implementation of the ELD system positively associate with safety outcomes?

To understand safety outcomes that align with the implementation of the ELD system, data on crashes of large trucks were analyzed. Crash data of large trucks were used from the National Highway Traffic Safety Administration's (NHTSA) Fatality Analysis Reporting System (FARS) database [45]. This allowed a quantitative comparison with the trends from the qualitative research listed above. Data were analyzed starting in 2014 to help with a baseline since 2014 was the year before the ELD phase-in. The database contained annual data up to 2019 when full ELD compliance was completed.

The FARS database provides three sets of data with increasing normalization. For the purposes of this paper we examined the most normalized set and a full description of all three data sets can be found in previous research [46].

The third set of data normalizes the crash data to miles driven. This accounts for the actual use of large trucks on the road. The trend in Figure 2 showed a sigmoid relationship. Specifically, when the ELD system was implemented crashes continued to rise and then leveled off from 2017 to 2018, with a jump in 2019 during the final phase of implementation. The rise in crash rate may be damped by the increased rest from the

mandatory break and rest period between days. However, this rise matched the comments from the drivers of speeding, driving while sick, and through heavy traffic to compensate for the ELD driving time limits. As experienced drivers who know how a workday unfolds and can adjust to unforeseen road conditions retire, they are replaced by new drivers with less experience. These new drivers join the ranks only experiencing the ELD clock and the anxiety it may bring. For example a driver with only 4 years of experience explained his experience with the ELD system this way: "[The] ELD messes you up, the clock still runs. So you rush." This suggests that early career drivers may react unpredictably compared to seasoned drivers and engage in unsafe behaviors that increase the crash rate.

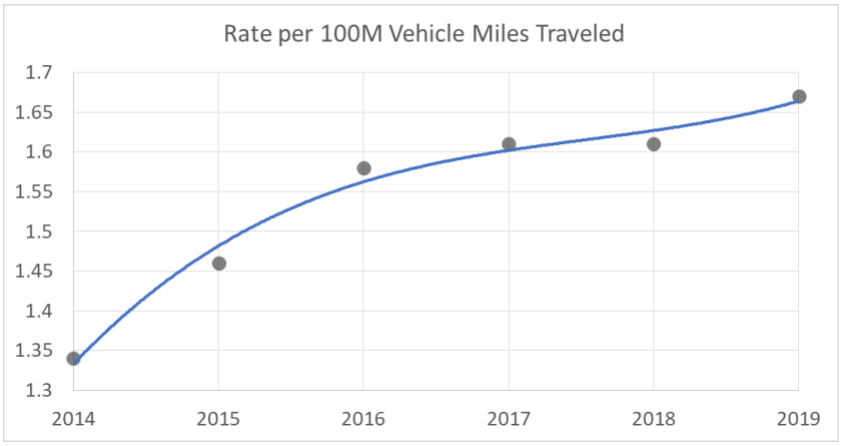

Figure 2. Crash rate per 100M miles driven by large trucks [45]

5. DISCUSSION & CONCLUSION

This purpose of this research was to understand the connection between safety culture and behaviors, particularly in lone-workers that may not have direct contact with

their supervisor/organization on a regular basis. We examined the factors of positive and negative influence and the effect on safety behaviors in long-haul truck drivers. The implementation of the ELD system allowed us to examine the intersection of the ELD technology, regulations, and truck drivers. This was critical to understand the links between a safety culture and safety outcomes among long-haul, lone-worker truck drivers as the ELD system arguably serves as a proxy for safety supervision.

The background research helped mold four research questions. RQ #1, Can a safety culture be identified among long-haul truck drivers, particularly considering their lone-worker status? RQ #2, Given that long-haul truck drivers are classified as lone-workers, what influence does the ELD system have on their safety behaviors? RQ #3, Do links exist between safety culture, safety influences, safety climate, and safety outcomes for long-haul truck drivers? RQ #4, Since the ELD system is both a safety system and a proxy for supervision, did the implementation of the ELD system positively associate with safety outcomes? The background research also helped form our research process which included direct access to truck drivers in their working environment.

To answer the first research question, Can a safety culture be identified among long-haul truck drivers, particularly considering their lone-worker status? We were able to identify four themes tied into cultural aspects among several drivers. The four themes included a practice of following the un-written rules over the formal rules, a value focused on human life, a value of money, and a value of following the law. Practices and values comprise a culture according to the background literature. This helped build a foundation of why certain safety behaviors were later identified.

The second question focused on influence and asked what influence does the ELD system have on the safety behavior of long-haul truck drivers? Two themes were identified that help answer this question. The first was a positive shift to comply with the ELD and the second was a shift to negative safety behaviors to compensate for the ELD driving limits. In both cases the ELD served as a supervisor of time for lone-worker truck drivers. The reaction to this depended on the drivers and they split in nearly identical sized groups with no connection to demographic data. Fifteen out of forty drivers took a positive approach and let the ELD system influence them to get more rest. The other group contained sixteen of the forty interviews with the remaining nine indicating they were not influenced by the ELD. The sixteen responded to a more concerning influence and reported speeding, driving while tired, and parking in unsafe areas. Though it was unexpected to have two divergent themes, they did answer the question that the ELD is having a clear influence on safety behaviors of long-haul truck drivers.

The third research question asked if links existed between safety culture, safety influences, safety climate, and safety outcomes for long-haul truck drivers? Safety culture was established by RQ #1 and influences were addressed in RQ #2. These helped identify two separate linkages that supported this third research question. Links tied to valuing money and a practice of how drivers adapted to changes in logging their driving time were documented. As the ELD system was implemented drivers reported their wages changing because they drove less to comply with the ELD system. They also reported reduced pressure to drive and more rest because of complying with the ELD

system. These two responses both support that links do exist from safety culture to safety influences, to safety climate in long-haul truck drivers.

The last research question focused on safety outcomes. Given that long-haul truck drivers align with the understanding of lone-workers, did the implementation of the ELD system positively associate with safety outcomes? This question is more interesting after capturing the results above. In RQ #2 drivers reported getting more rest which would decrease fatigue and should improve safety outcomes, while others admitted to unsafe behaviors that should lead to unsafe outcomes. Safety outcome data taken across a large group of drivers might not show a clear trend because both the safe and unsafe behaviors might cancel each other out.

We analyzed crash data from a large group of truck drivers. Of the available data the most normalized fit the context of this research best. It showed an interesting sigmoid shape to the crash rate trend with time. This shape aligned with what the drivers were reporting, that in several cases they were engaging in unsafe behaviors to compensate for the ELD driving limits. It is possible that their unsafe behavior is associated with increased crash rate and improved rest is leveling safety outcomes as the ELD system was implemented. With the increased crash rate in 2019 it is also possible that another influence is causing the trend in the data. Since we are unable to decouple the two linkages and unable to strengthen the association of ELD implementation with safety outcomes, RQ #4 remains to be answered by future research.

Research into safety culture and safety climate have largely been separate. This work was partially focused on bridging the two, along with understanding if links existed in lone-workers between safety culture, safety influences, safety climate, and safety

outcomes. Some of these links were established, showing that a safety culture does exist in truck drivers and that safety culture can be connected to safety climate, up to the beginnings of safety outcomes. This bridged safety culture and safety climate, paving the way for future work to strengthen the connection. The ELD implementation that helped with this connection also created a valuable research opportunity for lone-workers. The ELD technology that constantly monitored drivers served as a proxy for supervision to the point drivers reported feeling anxiety and dread. There were connections of the implementation of the ELD to both positive safety behaviors like increased rest and negative safety behaviors such as speeding. This showed that in lone-workers there are common attributes that can be researched. Future research could delve into other lone-works to see if similar connections exist, or if the findings in this research are isolated to truck drivers. If a safety culture and climate do exist it opens opportunities for other systems to build on the ELD learning to improve safety outcomes.

REFERENCES

1. Federal Register. 2015; 80:241. Available from: https://www.govinfo.gov/content/pkg/FR-2015-12-16/pdf/FR-2015-12-16.pdf

2. U.S. Bureau of Labor Statistics. 2021. Available from: https://www.bls.gov/charts/census-of-fatal-occupational-injuries/fatal-occupational-injuries-by-event-drilldown.htm

3. Zohar, D. Safety climate in industrial organizations: Theoretical and applied implications. Journal of Applied Psychology 1980; 65:96–102.

4. International Nuclear Safety Advisory Group. Summary Report on the Post-Accident Review Meeting on the Chernobyl Accident 1986; Safety Series No.75-INSAG-1.

5. Cox, S. and Cox, T. Safety, systems and people. Current Psychology 1996; 18:5-17.

6. Glick, W. Conceptualizing and measuring organizational and psychological climate: pitfalls in multilevel research. Academy of Management Review 1985; 10:601-616.

7. Reichers, A. and Schneider, B. Climate and culture: an evolution of constructs. Organizational Climate and Culture 1990; 5-39.

8. Moran, T. and Volkwein, F. The cultural approach to the formation of organizational climate. Human Relations 1992; 45:19-47.

9. Furnham. The Psychology of Behaviour at Work. Psychology Press 1997

10. Mearns, K., Flin, R., Fleming, M. and Gordon, R. Organizational and Human Factors in Offshore Safety. 1997, OTH 97 543.

11. Griffin, M. & Neal, A. Perceptions of safety at work: A framework for linking safety climate to safety performance, knowledge, and motivation. Journal of Occupational Health Psychology 2000; 5:3.

12. Zohar, D. A group-level model of safety climate: Testing the effect of group climate on microaccidents in manufacturing jobs. Journal of Applied Psychology 2000; 85: 587–596.

13. Brown, R.L. and Holmes, H. The use of factor-analytic procedure for assessing the validity of an employee safety climate model. Accident Analysis and Prevention 1986; 18:289-297.

14. Dedobbeleer, N., & Béland, F. A safety climate measure for construction sites. Journal of safety research 1991; 22:97-103.

15. Cox, S., & Flin, R. Safety culture: philosopher's stone or man of straw?. Work & Stress 1998; 12: 189-201.

16. Mearns, K. & Flin, R. Assessing the state of organizational safety - Culture or climate? Current Psychology 1999; 18:5-17.

17. Ostroff, C., Kinicki, A.J. & Muhammad, R.S. Organizational culture and climate. Handbook of Psychology, Vol 12: Industrial and Organizational Psychology 2012; 643-676.

18. Huang, Y. H., Zohar, D., Robertson, M. M., Garabet, A., Lee, J., & Murphy, L. A. Development and validation of safety climate scales for lone workers using truck drivers as exemplar. Transportation Research Part F: Traffic Psychology and Behavior 2013; 17:5–19.

19. Schneider, B., Ehrhart, M., Macey, W. Organizational climate and culture. Annual Review of Psychology 2013; 64:361-388.

20. Neal, A., & Griffin, M. A. A study of the lagged relationships among safety climate, safety motivation, safety behavior, and accidents at the individual and group levels. Journal of applied psychology 2006; 91:946.

21. Brown, R. L., & Holmes, H. The use of a factor-analytic procedure for assessing the validity of an employee safety climate model. Accident Analysis & Prevention 1986; 18:455-470.

22. Cox, S. and Cox, T. The structure of employee attitudes to safety: a European example. Work and Stress 1991; 5:93-106.

23. Alexander, M., Cox, S., and Cheyne, A. UK Offshore Safety Culture. Paper presented at the "Understanding Risk Perception" Conference. Aberdeen 1995.

24. Lee. T.R. The role of attitudes in the safety culture and how to change them. Paper presented at the "Understanding Risk Perception" Conference. Aberdeen 1995.

25. Williamson, A., Feyer, A-M., Cairns, D., and Biancotti, D. The development of a measure of safety climate: the role of safety perceptions and attitudes. Safety Science 1997; 25:15-27.

26. Schneider, B., Salvaggio, A. N., & Subirats, M. Climate strength: a new direction for climate research. Journal of applied psychology 2002; 87:220.

27. Zohar, D., Huang, Y. H., Lee, J., & Robertson, M. A mediation model linking dispatcher leadership and work ownership with safety climate as predictors of truck driver safety performance. Accident Analysis & Prevention 2014; 62:17-25.

28. Huang, Y. H., Robertson, M. M., Lee, J., Rineer, J., Murphy, L. A., Garabet, A., & Dainoff, M. J. Supervisory interpretation of safety climate versus employee safety climate perception: Association with safety behavior and outcomes for lone workers. Transportation research part F: traffic psychology and behavior 2014; 26:348-360.

29. Mearns, K., Flirt, A., Gordon, R., and O'Connor, P. Factoring the human into safety: Translating research into practice. Department of Psychology, University of Aberdeen 1997.

30. Hughes, P., & Ferrett, E. Introduction to Health and Safety at Work Revision Cards. Routledge. 2009; 117.

31. British Security Industry Association (BSIA). Lone workers guidance. 2010. Available from: https://www.bsia.co.uk/publications/lone-worker

32. Brennan, W. Managing risks to lone workers. Occupational Health & Wellbeing. 2012; 64:27.

33. Agnew, J., Hyten, C., & Sevin, B. Lone Worker Safety. Professional Safety 2017; 62: 22.

34. Schneider, B. The People Make the Place. Personnel Psychology. 1987; 40: 437 - 453.

35. Arboleda, A., Morrow, P. C., Crum, M. R., & Shelley, M. C. II. Management practices as antecedents of safety culture within the trucking industry: Similarities and differences by hierarchical level. Journal of Safety Research 2003; 34:189–197.

36. Geller, E. S. The psychology of safety: How to improve behaviors and attitudes on the job. Chilton Book Company 1996.

37. Wills, A. R., Watson, B., & Biggs, H. C. Comparing safety climate factors as predictors of work-related driving behavior. Journal of safety research 2006; 37:375-383.

38. Wallace, J.C., Popp, E., Mondore, S., Safety climate as a mediator between foundation climates and occupational accidents: a group-level investigation. Journal of Applied Psychology 2006; 91:681–688.

39. Strahan, C., Watson, B., & Lennonb, A. Can organisational safety climate and occupational stress predict work-related driver fatigue?. Transportation research part F: traffic psychology and behavior 2008; 11:418-426.

40. Zohar, D., Huang, Y. H., Lee, J., & Robertson, M. A mediation model linking dispatcher leadership and work ownership with safety climate as predictors of truck driver safety performance. Accident Analysis & Prevention 2014; 62:17-25.

41. Federal Motor Carrier Safety Administration. Driver's Record of Duty Status. 2021. Available from: https://csa.fmcsa.dot.gov/safetyplanner/MyFiles/SubSections.aspx?ch=23&sec=69&sub=178

42. Federal Motor Carrier Safety Administration. Electronic Logging Devices 2021. Available from: https://eld.fmcsa.dot.gov/About

43. Federal Motor Carrier Safety Administration. Summary of Hours of Service Regulations 2021. Available from: https://www.fmcsa.dot.gov/regulations/hours-service/summary-hours-service-regulations

44. APA Dictionary of Psychology. Belief, Value, Practice, Attitude. 2021. Available from: https://dictionary.apa.org

45. National Highway Traffic Safety Administration. FARS Encyclopedia: Trends - General. 2021. Available from: https://www-fars.nhtsa.dot.gov/Trends/TrendsGeneral.aspx

46. Washburn, C., Murray, S., Kueny, C. Early Outcomes of the ELD System in the Trucking Industry. Professional Safety. in press.

SECTION

3. CONCLUSIONS AND RECOMMENDATIONS

3.1. CONCLUSIONS

This researched aimed to understand if a safety culture could be identified among long-haul truck drivers, and to identify the links between safety culture, safety climate, safety influences, safety behaviors, and safety outcomes in this group of lone-workers. This work also sought to understand when new safety technology is implemented, is there a positive association with safety outcomes? Qualitative research was undertaken to find answers to these questions.

3.1.1. Paper #1. The first paper explored how the implementation of the ELD system affected drivers. The intention of the ELD systems was to improve both safety on the roads and the economy of the trucking industry. The goal was to dig into this and understand what was motivating the driver's behavior. It was learned that drivers were compensating for the limited driving time the ELD place on them by driving faster. Additional knowledge was gained around how the ELD made them feel. With a rigid system and a clock counting down drivers reported feeling like robots and not being able to use their professional judgment to manage challenges on the road. The ELD system also alleviated pressure on drivers to alter their records and drive when they were tired.

To compare driver's comments about increased crashes from the ELD implementation, data from the National Highway Traffic Safety Administration's (NHTSA) Fatality Analysis Reporting System (FARS) was plotted to see if there was an

association. Three charts were examined and did show an increase in crashes through ELD implementation, up to 2018. After the first paper was submitted for publication 2019 data was released and showed a more complex sigmoid relationship, indicating after an increase crashes started to level off.

This first paper helped to understand that a rigid system with no flexibility removes the ability for drivers to alter their records and also removes some of the value of having a human as part of the system. There were also reports that the lack of flexibility caused unsafe behaviors of speeding and driving while sick, since drivers were unable to adapt to changing conditions. This showed that the ELD implementation did have the desired effect of improving the economy of trucking and increased opportunities for drivers to rest, but it also created an unintended effect of motivating drivers to engage in unsafe behaviors which was supported by crash data.

3.1.2. Paper #2. The second paper went deep into the relationships of safety concepts. Four research questions were formed to understand these relationships, which included identifying a safety culture, influence of the ELD system, links between safety concepts, and association with safety outcomes. Themes from coding the research helped to positively answer the first two research questions. This established that a safety culture did exist in long-haul truck drivers, and both positive and negative influences on safety behavior came from the ELD implementation. The first question increased knowledge by broadening the understanding of what groups a safety culture can exist in. The second question provided insight into how a safety system is influencing this same group, providing knowledge on how to improve future systems.

By integrating the first two research questions the answer for the third research question emerged. It was shown that links do exist between safety culture, safety influences, and safety climate. This was important because the understanding of safety culture and climate indicated they might not exist in workers who are away from others while doing their job. The last research question was not answered due to constraints in associating the implementation in the ELD across the uncontrolled environment of the open road and many years to phase in the ELD system. The knowledge gained from the research did indicate that the positive and negative behaviors might cancel each other out across a large enough data set. There was a near 50/50 split across the participants on the positive and negative sides and the sample was diverse, so this split supports the theory.

3.2. REFLECTIONS & RECOMMENDATIONS

This research addressed gaps in our knowledge of safety culture and safety climate in lone-workers noted above. It also brought both safety culture and safety climate together, which have been separate for the majority of research prior to this study. It's important to connect them to further our understanding because of the links between them. It's also important to connect them if we want to improve safety, because of the influence they have on behaviors.

The timing of this work was fortuitous. Right after the interviews were complete, the world plunged into a pandemic. The driving conditions changed as people stayed home. To improve the flow of goods the Federal Motor Carrier Safety Association (FMCSA) changed driving rules. The new rules allowed drivers with learning permits to drive before they earned their CDL and increased the time limits so drivers could drive

longer (FMCSA 2020). This created a temporary new normal. Until the world fully recovers from the pandemic the pre-pandemic context of this research should be considered.

Complex problems often need complex solutions. When trying to determine how to improve driver safety the solution was a rigid ELD system. This did place hard limits on how long drivers were driving and how long they had to rest. The consequence was that some drivers responded with dread and anxiety of not completing a delivery or being caught on the open road in an unsafe location. The risk of too simple a solution is that it can create a secondary problem, which appeared to be the case with the ELD system. Future safety systems should consider how to build in flexibility so that drivers can get credit for resting when they are loading, can stop to avoid traffic or weather, and can take a break for biologic needs without fear of consequences. Possibly a combination of hours and miles as a limit similar to gaining status on airlines. This would allow drivers to compensate for unplanned events while increasing opportunities for them to be safer. Future safety systems should also consider how to limit unsafe behaviors such as speeding, which counteract the intent of improving road safety.

An understanding of safety culture could be used to improve safety behaviors. With the links established between safety culture, safety climate, safety influences and safety behaviors, changing safety culture of truck drivers can adjust safety behaviors. The values and the practice that signaled a safety culture can become mechanisms to adjust safety climate, shift safety influences, and improve safety behaviors.

Future work could include understanding the cause-and-effect of these mechanisms to produce improved safety behaviors. Future work could also explore if the

knowledge gained through this research applies to other lone-worker groups. This work could help to understand if a safety culture is similar among similar groups or not, and help to understand if cause-and-effect would work the same way. Future work is also needed to explore the connection of safety culture and safety climate across other areas of industry. Work is also needed to connect this research to safety outcomes so that road safety such as incidents and accidents can be reduced.

BIBLIOGRAPHY

Agnew, J., Hyten, C., & Sevin, B. (2017). Lone Worker Safety. Professional Safety, 62(1), 22.

Alruqi, W., Hallowell, M., Techera, U. (2018). Safety climate dimensions and their relationship to construction safety performance: A meta-analytic review. Safety Science, 109, 165-173.

Andersen, L., Nørdam, L., Joensson, T., Kines, P., Nielsen, K. (2018). Social identity, safety climate and self-reported accidents among construction workers, Construction Management and Economics, 36:1, 22-31.

Arboleda, A., Morrow, P. C., Crum, M. R., & Shelley II, M. C. (2003). Management practices as antecedents of safety culture within the trucking industry: similarities and differences by hierarchical level. Journal of safety research, 34(2), 189-197.

Bamel, U., Pandey, R., Gupta, A. (2020). Safety climate: Systematic literature network analysis of 38 years (1980-2018) of research. Accident Analysis & Prevention, 135.

Bergman, M. E., Payne, S. C., Taylor, A. B., & Beus, J. M. (2014). The Shelf Life of a Safety Climate Assessment: How Long Until the Relationship with Safety-Critical Incidents Expires?. Journal of business and psychology, 29(4), 519–540.

Beus, J. M., Payne, S. C., Bergman, M. E., & Arthur, W. (2010). Safety climate and injuries: an examination of theoretical and empirical relationships. The Journal of applied psychology, 95(4), 713–727.

Brennan, W. (2012). Managing risks to lone workers. Occupational Health & Wellbeing, 64(12), 27.

British Security Industry Association (BSIA). (2010) Lone workers guidance. Available from: https://www.bsia.co.uk/publications/lone-worker

Brown, R. L., & Holmes, H. (1986). The use of a factor-analytic procedure for assessing the validity of an employee safety climate model. Accident Analysis & Prevention, 18(6), 455-470.

Carroll, J. S. (1998). Safety culture as an ongoing process: Culture surveys as opportunities for enquiry and change. Work and Stress, 12(3), 272-284.

Christian, M. S., Bradley, J. C., Wallace, J. C., & Burke, M. J. (2009). Workplace safety: A meta-analysis of the roles of person and situation factors. Journal of Applied Psychology, 94(5), 1103–1127.

Clarke, J. (2010). An integrative model of safety climate: Linking psychological climate and work attitudes to individual safety outcomes using meta-analysis. Occup. Org. Psychol., 83 (3), 553-578.

Clarke, S. (1999). Perceptions of organizational safety: Implications for the development of safety culture. Journal of Organizational Behaviour, 20, 185-198.

Collins, J. A., Hagan, B. T., & Bratt, H. M. (1976). The failure-experience matrix—a useful design tool.

Cooke, R. A., & Lafferty, J. C. (1989). Organizational Culture Inventory: OCI. Plymouth, MI: Human Synergistics.

Cox, S., & Cox, T. (1996). Safety, Systems and People. Oxford: Butterworth-Heinemann.

Cox, S., & Flin, R. (1998). Safety culture: philosopher's stone or man of straw?. Work & stress, 12(3), 189-201.

Dedobbeleer, N., & Béland, F. (1991). A safety climate measure for construction sites. Journal of safety research, 22(2), 97-103.

DeJoy, D. M., Schaffer, B. S., Wilson, M. G., Vandenberg, R. J., & Butts, M. M. (2004). Creating safer workplaces: assessing the determinants and role of safety climate. Journal of safety research, 35(1), 81–90.

Denison, D. R. (1996). What is the difference between organizational culture and organizational climate. A native's point of view on a decade of paradigm wars.

Department of Defense. (1949). Procedure for performing a failure mode effect and criticality analysis. (MIL-P-1629). Washington, DC: U.S. Government Printing Office.

Ericson, C. (1999). “Fault tree analysis - a history”. Proceedings of the 17th International System Safety Conference, Orlando Florida.

Federal Motor Carrier Safety Administration. (2020). US Department of Transportation Issues National Emergency Declaration for Commercial Vehicles Delivering Relief in Response to the Coronavirus Outbreak [press release]. Retrieved from https://www.fmcsa.dot.gov/newsroom/us-department-transportation-issues-national-emergency-declaration-commercial-vehicles

Federal Register. (2008, November 19). Federal Register Vol. 73, No.224. https://www.govinfo.gov/content/pkg/FR-2008-11-19/pdf/FR-2008-11-19.pdf

Federal Register. (2015). 80:241. Available from: https://www.govinfo.gov/content/pkg/FR-2015-12-16/pdf/FR-2015-12-16.pdf

Ferrett, E. (2009). Introduction to Health and Safety at Work Revision Cards. Routledge. FMCSA. ELD Fact Sheet. https://www.fmcsa.dot.gov/hours-service/elds/eld-fact-sheet-english-version

Furnham, A. (2012). The psychology of behaviour at work: The individual in the organization. Psychology press.

Geller, E. S. (1996). The psychology of safety: How to improve behaviors and attitudes on the job. Chilton Book Company.

Ginsburg, L., & Gilin Oore, D. (2016). Patient safety climate strength: a concept that requires more attention. BMJ quality & safety, 25(9), 680–687.

Glick, W. H. (1985). Conceptualizing and Measuring Organizational and Psychological Climate: Pitfalls in Multilevel Research. The Academy of Management Review, 10(3), 601–616.

Goldenhar, L. J., Williams, L. J., Swanson, N. G. (2003). Modelling relationships between job stressors and near-miss outcomes for construction labourers. Work&Stress.

Grantham Lough, K., Stone, R., & Tumer, I. (2008). Failure Prevention in Design Through Effective Catalogue Utilization of Historical Failure Events. Journal of Failure Analysis & Prevention, 8(5).

Griffin, M. & Neal, A. (2000). Perceptions of safety at work: A framework for linking safety climate to safety performance, knowledge, and motivation. Journal of Occupational Health Psychology. 5(3).

Haque, M. M., & Washington, S. (2014). A parametric duration model of the reaction times of drivers distracted by mobile phone conversations. Accident; analysis and prevention, 62, 42–53.

Hawkins, P. G., & Woollons, D. J. (1998). Failure modes and effects analysis of complex engineering systems using functional models. Artificial intelligence in engineering, 12(4), 375-397.

He, Y., Wang, Y., Payne, S. (2019). How is safety climate formed? A meta-analysis of the antecedents of safety climate. Organizational Psychology Review. 9.

Hofmann, D. A., & Mark, B. (2006). An investigation of the relationship between safety climate and medication errors as well as other nurse and patient outcomes. Personnel Psychology, 59(4), 847–869.

Holland, C., & Rathod, V. (2013). Influence of personal mobile phone ringing and usual intention to answer on driver error. Accident; analysis and prevention, 50, 793–800.

Hon, C. K., Hinze, J., & Chan, A. P. (2014). Safety climate and injury occurrence of repair, maintenance, minor alteration and addition works: A comparison of workers, supervisors and managers. Facilities.

Hours of Service of Drivers, 49 C.F.R. § 395 (2021).

Huang, Y. H., Robertson, M. M., Lee, J., Rineer, J., Murphy, L. A., Garabet, A., & Dainoff, M. J. (2014). Supervisory interpretation of safety climate versus employee safety climate perception: Association with safety behavior and outcomes for lone workers. Transportation research part F: traffic psychology and behaviour, 26, 348-360.

Huang, Y. H., Zohar, D., Robertson, M. M., Garabet, A., Lee, J., & Murphy, L. A. (2013). Development and validation of safety climate scales for lone workers using truck drivers as exemplar. Transportation Research Part F: Traffic Psychology and Behavior, 17, 5–19.

Hughes, P., & Ferret, E. (2009). Introduction to health and safety at work. Oxford: Butterworth-Heinemann.

International Nuclear Safety Advisory Group. (1986). Summary Report on the Post-Accident Review Meeting on the Chernobyl Accident. Safety Series No.75-INSAG-1.

Jiang, L., Lavaysse, L. M., & Probst, T. M. (2019). Safety climate and safety outcomes: A meta-analytic comparison of universal vs. industry-specific safety climate predictive validity. Work & Stress, 33(1), 41-57.

Kletz, T.A. (1988). What went wrong? — case histories of process plant disasters (2nd ed.). Houston, TX : Gulf Publishing.

Kumamoto, H., Henley, E. (1996) Probabilistic Risk Assessment and Management for Engineers and Scientists. New York: IEEE Press.

Lee, T. (1998). Assessment of safety culture at a nuclear reprocessing plant. Work and Stress, 12, 217-237.

Lingard, H., Cooke, T., & Blismas, N. (2012). Do perceptions of supervisors' safety responses mediate the relationship between perceptions of the organizational safety climate and incident rates in the construction supply chain?. Journal of Construction Engineering and Management, 138(2), 234-241.

Luo, T. (2020). Safety climate: Current status of the research and future prospects. Journal of Safety Science and Resilience, 1 (2), 106-119.

Mearns, K. & Flin, R. (1999). Assessing the state of organizational safety - Culture or climate? Current Psychology, Spring, vol. 18(1), 5-17.

Mearns, K. Flin, R., Gordon R., Fleming, M. (2001). Human and organizational factors in offshore safety, Work & Stress, 15(2), 144-160.

Moran, E. & Volkwein, J.. (1992). The Cultural Approach to the Formation of Organizational Climate. Human Relations - HUM RELAT. 45. 19-47.

Nahrgang, J. D., Morgeson, F. P., & Hofmann, D. A. (2007). Predicting safety performance: A meta-analysis of safety and organizational constructs. In 22nd annual conference of the society for industrial and organizational psychology, New York.

Neal, A., & Griffin, M. A. (2006). A study of the lagged relationships among safety climate, safety motivation, safety behavior, and accidents at the individual and group levels. Journal of Applied Psychology, 91(4), 946–953.

Neal, A., & Griffin, M. A. (2006). A study of the lagged relationships among safety climate, safety motivation, safety behavior, and accidents at the individual and group levels. Journal of applied psychology, 91(4), 946.

Ochs, M. (2017). How A Trucker's Protest Anthem Became A '70s Hit [Radio broadcast]. National Public Radio https://www.npr.org/2017/06/06/531749486/the-legacy-of-convoy-how-a-trucker-s-protest-anthem-became-a-70s-hit

Ostroff, C., Kinicki, A.J. & Muhammad, R.S. (2012) Organizational culture and climate. In Weiner, I.B., Schmitt, N.W. & Highhouse, S., Handbook of Psychology, Vol 12: Industrial and Organizational Psychology, 643-676. Hoboken, NJ: John Wiley & Sons.

Reichers, A. and Schneider, B. (1990). Climate and culture: an evolution of constructs. In B. Schneider (ed.) Organisational Climate and Culture, 5-39. San Francisco, Jossey Bass.

Roberts, K. H., Rousseau, D. M., & La Porte, T. R. (1994). The culture of high reliability: Quantitative and qualitative assessment aboard nuclear-powered aircraft carriers. Journal of High Technology Management Research, 5, 141-161.

Schneider, B. (1987). The people make the place. Personnel psychology, 40(3), 437-453.

Schneider, B. (1990). Organizational climate and culture. San Francisco: Jossey-Bass.

Schneider, B., Ehrhart, M. G., & Macey, W. H. (2013). Organizational climate and culture. Annual review of psychology, 64, 361-388.

Strahan, C., Watson, B., & Lennonb, A. (2008). Can organisational safety climate and occupational stress predict work-related driver fatigue?. Transportation research part F: traffic psychology and behaviour, 11(6), 418-426.

Strayer, D., Cooper, J., Turrill, J., Coleman, J., Ward, N., Biondi, F. (2013). Measuring Cognitive Distraction in the Automobile. AAA foundation for traffic Safety.

Tumer, I. Y., Stone, R. B., & Bell, D. G. (2003). Requirements for a failure mode taxonomy for use in conceptual design. In DS 31: Proceedings of ICED 03, the 14th International Conference on Engineering Design, Stockholm.

U.S. Bureau of Labor Statistics (2019). Census of Fatal Occupational Injuries. Retrieved October 9, 2021, from https://www.bls.gov/charts/census-of-fatal-occupational-injuries/fatal-occupational-injuries-by-event-drilldown.htm

U.S. Bureau of Labor Statistics (2019). Injuries, illnesses, and fatalities. Retrieved October 9, 2021, from https://www.bls.gov/iif/oshover.htm

Venkatasubramanian, V., Zhao, J., & Viswanathan, S. (2000). Intelligent systems for HAZOP analysis of complex process plants. Computers & Chemical Engineering, 24(9-10), 2291-2302.

Vogus T. J. (2016). Safety climate strength: a promising construct for safety research and practice. BMJ quality & safety, 25(9), 649–652.

Walker, E., Hernandex, A., Kattan, M. (2008). Meta-analysis: Its strengths and limitations. Cleveland Clinic Journal of Medicine, 75 (6) 431-439.

Wallace, J. C., Popp, E., & Mondore, S. (2006). Safety climate as a mediator between foundation climates and occupational accidents: A group-level investigation. Journal of applied psychology, 91(3), 681.

Washburn, C. A. (2012). Chemical risk in early design. Missouri University of Science and Technology. Masters Theses.

Wickens, C., Lee, J., Liu, Y., Gordon-Becker, S. (2015) Introduction to Human Factors Engineering (2nd edition). Pearson.

Wills, A. R., Watson, B., & Biggs, H. C. (2006). Comparing safety climate factors as predictors of work-related driving behavior. Journal of safety research, 37(4), 375-383.

Zohar, D. (1980). Safety climate in industrial organizations: Theoretical and applied implications. Journal of Applied Psychology, 65, 96–102.

Zohar, D. (2000). A group-level model of safety climate: Testing the effect of group climate on microaccidents in manufacturing jobs. Journal of Applied Psychology, 85(4), 587–596.

Zohar D. (2003). Safety climate: Conceptual and measurement issues. In: Tetrick LE, Quick JC, editors. Handbook of occupational health psychology. Washington, DC: American Psychological Association. 123–142.

Zohar D. (2011). Safety climate: Conceptual and measurement issues. In: Quick JC, Tetrick LE, editors. Handbook of Occupational Health Psychology. 2. Washington, DC: American Psychological Association. 141–164.

Zohar, D., Huang, Y. H., Lee, J., & Robertson, M. (2014). A mediation model linking dispatcher leadership and work ownership with safety climate as predictors of truck driver safety performance. *Accident Analysis & Prevention*, *62*, 17-25.

VITA

Carlton Ashley Washburn was an engineer who has focused at intersections during his career. For this work it was the intersection of engineering and psychology.

Carlton earned a Bachelor of Science in Physics from Illinois College in December 2002, Bachelor of Science in Mechanical Engineering from Missouri University of Science and Technology in December 2002, Master of Science in Engineering Management from Missouri University of Science and Technology in December 2012, and Doctor of Philosophy in Engineering Management from Missouri University of Science and Technology in December 2021.