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The attached seminar paper, by James P. Rubocki, entitled Application of Artificial Intelligence in the Trucking Industry, when completed, is to be submitted to the Graduate Faculty of the University of Wisconsin-Platteville in partial fulfillment of the requirement for the (MASTER OF SCIENCE IN INTEGRATED SUPPLY CHAIN MANAGEMENT) degree.

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Application of Artificial Intelligence in the Trucking Industry21

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James P. Rubocki

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Thank you for all of your support.

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ABSTRACT

The U.S. trucking industry has a shortage of truck drivers. This is an issue that became apparent in the early 2000s and continues to grow each year. The truck driver shortage has the potential to directly impact all consumers within the U.S. economy. The trucking industry is responsible for delivering the majority of all raw material to manufacturing facilities and finished goods to retail outlets. Shippers can expect to pay increased transportation costs as the capacity within the trucking industry is restricted, a cost that will likely be passed to consumers in the form of higher prices for consumer goods. Artificial intelligence (AI) offers a possible solution to the truck driver shortage. Automated and autonomous vehicles that rely on AI technology have the potential to increase the productivity of truck drivers and attract new drivers to the industry. While fully autonomous vehicles are not expected to be available for several decades, AI-enabled automated vehicles may be commercially available within the next decade.

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I. Introduction

Statement of the problem

Within the U.S. commercial trucking industry there is an old saying that states, “If it got there, a truck brought it.” (Garver, LeMay, Johnson & Williams, 2013). Recent data reinforces this saying by showing trucking dominates all other modes of freight transportation within the U.S. In 2017, the American Trucking Associations (ATA) reports 70.6 percent of all freight tonnage was transported via truck (Costello, 2017). Congressional Research Service states the trucking industry is responsible for nearly 75 percent of all freight transportation when measured in tonnage or cargo value (Fritelli, 2016). The demand for the trucking industry’s freight transportation is derived from the collective final demand for consumer goods. This has led to many people viewing the trucking industry as the “backbone of the U.S. economy.” (Bass, 2004). The demand for the trucking industry’s services is projected to remain strong for decades to come. The United States Department of Transportation (USDOT) projects this demand to increase 1.4 percent per year through 2045 (Sprung, 2017).

In order to meet the increased demand for services the trucking industry must address the problem of their driver shortage. The problem has persisted for at least two decades. In the mid-2000s there was a reported shortage of 20,000 drivers (Mundahl, 2017). Data from 2016 shows the shortage increased to approximately 36,500 drivers. The shortage has the potential to reach 174,000 by 2026 if corrective measures are not implemented (Costello, 2017). There are several causes of the driver shortage. Among the most significant causes are the retirement rate of current drivers, expansion of the trucking industry, and driver turnover. The trucking industry is comprised of a large number of baby-boomers that has resulted in the average age of a truck driver across all segments of the industry to reach “46.5, compared to 42.4 for the average

American worker." (Mundahl, 2017). As baby-boomers retire, it is estimated 220,000 drivers must be hired simply to replace the retiring drivers (Bristow, Johnson, McClure & Schneider, 2010). Driver turnover is a significant issue that is having a negative impact on the trucking industry. Companies are also experiencing difficulty in retaining qualified drivers. Some companies are reporting annual turnover rates as high as 150 percent. To make the problem even worse, half of all long-distance truck drivers quit within three months of being hired (Bristow et al., 2010).

Purpose of the research

The purpose of this research is to examine the causes of the truck driver shortage within the U.S. trucking industry. The research will also examine the status of artificial intelligence (AI) technology currently available and under development. This paper will examine ways in which AI can be applied within the trucking industry to mitigate risks associated with the truck driver shortage. A recent quote from Microsoft co-founder Bill Gates alludes to the potential for AI to increase the productivity of truck drivers when he stated AI is a technology that will enable the ability "to produce a lot more goods and services with less labor" (Marshall, 2018). AI is a concept that has been researched since the 1950s and has recently experienced a period of rapid development. The growth in AI research and application is evident in the number of scholarly articles that have been written on technology. The number of AI articles doubled from 2014 to 2015, and then again doubled from 2015 to 2016 (Allas et al., 2018). Much of the published AI research has focused on the application of AI within the transportation industry. Some researchers are optimistic this technology will have a significant impact on the trucking industry. Morgan Stanley conservatively projects AI technology could save $168 billion annually, with up to $70 billion resulting in staff reductions (Accenture Mobility, 2017). The AI induced staff reductions are a means to address the truck driver shortage.

Significance of the research

The U.S. economy heavily relies on the services provided by the trucking industry. Americans depend on truck drivers to deliver virtually everything they consume (Collins, 2013). The volume of products delivered via the trucking industry is evident by the number of semitrucks observed each day on the highway system. There are an estimated 4.3 million commercial trucks traversing the 220,000 miles of U.S. highways (Levandowski and Ron, 2016). Trucks are a popular mode of transportation because the highway system enables products to be reliably delivered anywhere throughout the country. However, the reliance on the trucking industry places the U.S. economy at risk in the event of disruptions to the trucking industry. The truck driver shortage, for example, has the potential to "cripple the U.S. economy" (Lambert and Min, 2002). The ramifications of this shortage will impact not only supply chain managers, but every consumer.

Assumptions

This research assumes the trucking industry will remain central to the effective functioning of the U.S. economy. Simply stated, "the trucking industry's dominance will remain unchallenged for the near future" (Iovan, 2007). This assumption is key as it indicates the driver shortage is an issue that must be addressed head on because there is no other viable mode of transportation that can currently transport the economy's freight. Additionally, this research assumes consumers will continue to demand products to be delivered with a short lead time, and that manufactures will continue to operate a "just-in-time" strategy. Both of these factors add to the demand for trucking industry services. Finally, this research is based on the assumption that research and development will continue with regards to the application of AI to automotive design.

Scope of the research

This research will focus solely on the application of AI technology to address the truck driver shortage. While trucking companies have a wide range of options to recruit and retain the most qualified drivers, this paper will be centered on the specific application of AI to address the driver shortage problem. Additionally, this research is limited to the application of narrow AI vice general AI because narrow AI has near-term business potential.

Methodology

The primary method for this research is the secondary data analysis of existing research and published literature relating to the trucking industry and AI. The causes behind the driver shortage will be examined and explained. The history of AI technology also will be examined in order to identify how it can serve as a potential solution to the truck driver shortage. The literature reviewed will include government reports, transportation-related professional journal articles and reports, and reports generated by industry partners that are economically invested in AI technology.

II. Literature Review

Trucking industry background

The trucking industry is a critical component of the U.S. economy, responsible for transporting products from the producers to the consumers. World War I witnessed the phasing out of horse-drawn wagons in exchange for vehicles powered by the internal combustion engine. Military logisticians during the war demonstrated the effectiveness of using trucks to distribute supplies to the fighting force. This new concept quickly became a common method to transport freight within the U.S. However, the majority of freight being transported long distances was still moved via the rail network. The trucking industry experienced rapid growth beginning in 1957 with the establishment of the Interstate Highway System. With the introduction of a reliable road network woven throughout the country, manufacturers and distributors were able to reduce their reliance on rail while still offering direct delivery service to customers (Belzer, Burks, Kwan, Pratt & Shackelford, 2010). The trucking industry as we know it today began to take shape. Growth of the trucking industry continued throughout the 20th century to the point where trucks became "the fundamental unit within the transportation sector" (ATA, 2015).

The trucking industry is a critical component to supply chain management (SCM) operations. According to the Institute for Supply Management, SCM is described as the coordination of "value added processes across organizational boundaries to meet the real needs of the end customer" (Leong, Tan & Wisner, 2012). There has been a recent change among many truck drivers that have embraced the concept of transportation providing a value-added service. Drivers have begun to appreciate the value they provide to the overall supply chain, instead of simply providing a commodity service (Collins, 2013). Effective supply chain managers can take advantage of the trucking industry to ensure products are delivered when and where they are demanded by the customers.

Transporting freight with the trucking industry offers several advantages over other modes of transportation. The primary advantage is convenience for the shipper. The trucking industry offers the shipper door-to-door delivery, frequent delivery options, and stable availability of service providers. Associated with convenience is that freight shipped door-to-door does not need to be loaded or offloaded between the origin and destination, as is typically the case with rail or air shipments (Ballou, 2004). Additionally, trucks are the most flexible mode of transportation service. They offer the ability to pick up at virtually any location the shipper is located, the transportation of small or large loads, and competitive pricing in relation to other modes of transportation (Leong, Tan & Wisner, 2012).

The trucking industry is generally separated between private and for-hire shippers or carriers, and parcel carriers. Private carriers are those that generally haul freight owned by their company. These carriers generally do not transport freight for other shippers. Wal-Mart is an example of a large-scale private carrier that operates a fleet of trucks to transport products to their stores (Belzer et al., 2010). For-hire shippers are carriers that offer transportation services for purpose of earning a profit transporting products owned by others. Common for-hire carriers include Schneider National, Yellow Corp, and Con-Way Transportation (Bass, 2004). United Parcel Service and Federal Express are two common parcel carriers. It is important to note that the Bureau of Labor Statistics uses a narrow definition of "trucking industry" when calculating statistics such as truck driver shortage. This narrow definition is limited to for-hire shippers or carriers (Belzer et al., 2010). Unless otherwise stated, information pertaining to driver shortage in the remainder of this paper is based on the Bureau of Labor Statistics definition.

Federal and state regulations

The trucking industry operates within the constraints of federal and state regulations. Within the federal government, the Department of Transportation (DOT) and one of its agencies, the Federal Motor Carrier Safety Administration (FMCSA), are responsible for establishing safety and operation regulations for all motorists. Three regulations that are the source of frequent criticism from the trucking industry are related to hours of service (HOS), electronic logging devices (ELD), and the minimum age requirement to earn a commercial driver license (CDL) (Peterman, 2018a).

The HOS regulation is a safety measure designed to protect truck drivers and motorists on the highway. This regulation remains in effect based on numerous studies concluding drivers become less attentive and more likely to be involved in crashes the more hours they operate (Peterman, 2018b). In 1935, Congress authorized the Bureau of Motor Carriers, the pre-cursor to the modern DOT, to issue the first HOS regulation (Peterman, 2018a). Current HOS regulations permit a truck driver to remain on-duty for 14 consecutive hours, with 11 of those hours allowed for driving. In order to drive the full 11 hours, a driver must complete a 30-minute break prior to reaching eight hours of on-duty time. Total on-duty time is limited to 60 hours over seven consecutive days, or 70 hours over eight consecutive days. Generally, the only way a driver can reset the 60/70 hour consecutive time period is to complete an off-duty period of 34 consecutive hours (Murray & Short, 2016).

The ELD mandate implemented in December 2017 requires truck drivers to replace paper logs of their HOS with electronic digital logs (Peterman, 2018b). The change to digital logs represents the biggest regulatory change to the trucking industry since the introduction of the CDL in the 1980s. This mandate applies to over 3 million commercial truck drivers that previously maintained paper logs of their HOS (Ashe & Cassidy, 2018). Implementation of the ELD is similar to the use of flight data recorders which have been a requirement within the airline industry for several decades (Collins, 2013). One reason the FMCSA mandated a change to the ELD is because truckers would often provide false data on the paper logs. Most truck drivers are paid by the mile, and therefore have an incentive to operate as many hours as possible. Violations of the HOS limits were relatively easy to hide with the analog paper logs. The ease of hiding violations produced a culture within the trucking industry where it was well known that truckers often drove beyond their HOS limits (Peterman, 2018a).

Initial data suggests the use of ELDs is effective in reducing the number of fatigued truck drivers on the road. Truck companies that voluntarily transitioned to ELDs prior to 2017 experienced a “drastic reduction in HOS violations” (Collins, 2013). Despite this data, some sectors within the trucking industry are complaining the ELD mandate is causing problems. The largest source of objection to the ELD mandate comes from livestock transporters. This group has indicated limitations on how long a truck driver can drive create a situation where livestock may be put at risk of heat if a stop is required prior to the final destination. However, the ELD mandate did not change the HOS limitations; it simply made it more difficult to dodge the limitations without getting caught. This suggests segments of the trucking industry have regularly been violating HOS limitations prior to the ELD mandate (Peterman, 2018b). It should be noted the FMCSA has since provided an exemption for livestock haulers. The new regulation waives the HOS limits and ELD mandate as long as the livestock hauler remains within a 150-air mile radius of their point of origin. Standard HOS and ELD requirements remain in effect when traveling beyond the 150-mile radius (Peterman, 2018b).

While well intentioned, the ELD mandate and HOS limits have resulted in higher rates for shippers. One reason for the rate increase is the recapitalization costs associated with purchasing ELD equipment and new trucks. Truck companies and owner-operators are responsible for retrofitting existing trucks with new ELD equipment. In order to maintain profits this new cost has been passed onto shippers in the form of higher shipping rates. Additionally, trucking companies or owner-operators could offset the cost of purchasing a new truck by trading in an old truck. However, many older trucks are not outfitted with ELD equipment, nor meet current emission standards. This has created a situation where offering a trade-in is not feasible, increasing the recapitalization cost of a new truck. Again, in order to maintain profits, this cost is passed on to the shipper in the form of higher rates (Collins, 2013).

Transportation capacity within the trucking industry has also been impacted by the ELD mandate. As early as 2013, prior to the ELD mandate, there was already a concern about the industry's ability to match the demand for transportation services. There was a general concern within the trucking industry that everything was not "fine with regard to truck capacity" (Collins, 2013). The capacity concern has been compounded by the ELD mandate. Ashe & Cassidy (2018) explain the most significant impact is seen on shipments between 450 and 550 miles. Data shows the average delivery between these distances was 1.05 days prior to the ELD mandate. The post-ELD mandate average delivery time has increased to 1.22 days, an increase of 16.2 percent. Due to the mandate, shippers are no longer willing to risk an HOS violation, so they are spreading more shipments across two days. Ashe & Cassidy (2018) also report an increasing number of shippers unwilling to support deliveries that would take 5-6 hours. While trips of this duration are within the HOS limits, often there is not enough on-duty time remaining for truck drivers to complete a backhaul run. This has set the conditions where shippers have been required to contact up to 50 trucking carriers before one would accept the transportation request.

Additional federal and state regulations impacting the trucking industry relate to the age requirement to obtain a CDL and engine idle restrictions. The current age for obtaining an interstate tractor trailer CDL is 21 years. This age minimum presents a challenge to recruiting interested and qualified individuals into the trucking industry. The current minimum age provides a barrier to 18-21-year-olds who otherwise may have entered the industry (Costello, 2017). With regards to idling restrictions, several states have limitations on the length of time a truck can sit in idle. While designed to protect the environment, the limitations offer a challenge to long haul truckers who utilize the sleeper berth in their trucks during required off-duty hours. A restriction on idling prevents truck drivers from using heat or air conditioning during periods when they should be relaxing and recovering (Belzer et al., 2010).

Truck driver shortage

The trucking industry is dealing with the problem of a truck driver shortage that threatens to have significant impacts on the U.S. economy. The truck driver shortage began to emerge in the late 1990s as the trucking industry continued to expand. In 1998 alone, the industry grew by $24 billion, causing many of the large carriers to increase truck driver wages an average of 10 percent. Despite the wage increases, driver turnover of between 92-103 percent was common among small and large carriers (Lambert & Min, 2002). These same issues remained within the trucking industry throughout the early 2010s. In 2012, the ATA reported a truck driver shortage of between 20,000 and 25,000 drivers, and a turnover rate of 98 percent (Collins, 2013). According to the most recent ATA reporting, the trucking industry must hire 89,000 new drivers a year for the next10 years in order to resolve the truck driver shortage. Replacing retiring drivers will account for the 49 percent of the new drivers. The current average age of commercial long-haul truck drivers is 49 years old-several years older than the overall average of all U.S. employees, which is approximately 42 (Costello, 2017). Other factors contributing to the driver shortage are increased demand for trucking industry services and driver turnover (Mundal, 2017). If not corrected, the truck driver shortage is a problem with potential to impact all U.S. consumers. Without corrective action the driver shortage could reach over 174,000 by 2026. The shortage will likely result in "severe supply chain disruptions resulting in significant shipping delays, higher inventory carrying costs, and perhaps shortages at stores" (Costello, 2017).

According to the ATA there are several factors that may impact the driver shortage in future years. A reduction of the federal age requirement for interstate CDLs from 21 to 18 years of age would expand the pool of applicants for the trucking industry. While a possible age reduction will likely not solve the truck driver shortage problem, it would provide the industry a certain level of relief (Costello, 2017). Less rigorous HOS limits may also provide relief for the truck driver shortage. While a change to HOS limits may not increase the total number of truck drivers within the industry, it would make current drivers more productive. As a result, fewer new drivers would need to be hired. Ashe and Cassidy (2018) conclude limiting the hours a truck driver can operate means the same number of drivers can complete fewer deliveries. Strict adherence to current HOS limits mean more drivers are required to accomplish the same number of deliveries.

The truck driver shortage also stems from the changing image of the trucking industry. Chafkin & Eidelson (2017) compare the image of the trucking industry from the 1977 movie *Smokey and the Bandit* to the reality of the industry today. The deregulation of the industry in 1980 by President Carter put in motion a series of events that eroded the nostalgic image portrayed in the movie. Following the deregulation, the majority of the short and routine runs that enabled truck drivers to spend most nights at home were replaced with long-haul deliveries causing drivers to be away from home for weeks at a time. Chafkin & Eidelson (2017) go on to explain the trucking industry is having a difficult time recruiting and retaining drivers because of the low average annual pay of roughly $40,000 combined with "work that is often unhealthy, painful, and lonely." Mundahl (2017) adds that recent regulations pertaining to how drivers can utilize their time, such as the ELD mandate, are harming the trucking industry by "cutting into the sense of flexibility and independence that drew people to the profession in previous years."

A 2010 survey of long-haul truck drivers provides additional insight into the causes of high driver turnover. The survey results based on 104 interviews of long-haul drivers were summarized by Bristow et al. (2010). Each participant was asked, "Other than pay, what one change in your work environment would improve your quality of life?" The top response to the question was the impact of government rules and regulations. Among these responses was a general opinion that truck drivers should have more flexibility determining when they can operate their truck, as opposed to the federal government limiting their hours. Other responses to the survey question included increased time at home, an increase in available truck parking, and improving the reputation of truck drivers and the trucking industry. (Appendix A provides a full list of responses.) Bristow et al. (2010) also asked participants why they feel the turnover rate among truck drivers is so high. The top response was associated with the challenges stemming from excessive amount of time spent away from home. Other top responses were employers lied to the drivers about the terms of employment, and truck drivers are lazy and unwilling to deal with the demands of the job. (Appendix B provides a full list of responses.)

Garver et al. (2013) provides additional insight into the factors that influence truck driver turnover. This report was based on analysis of 309 questionnaires completed by truck drivers using a Likert-style seven-point scale. Garver et al. (2013) concluded company reputation, recruiters, job safety, and time spent at home to be the most significant variables that influence retention and turnover. Company reputation likely influences driver turnover because drivers prefer to work for companies known for treating their drivers well. Recruiters can influence driver turnover because drivers that feel their recruiter lied about the job preview are more likely to terminate employment with the company. Finally, job safety and time at home indicate drivers are interested in working for a company that stresses safety procedures while also ensuring drivers maximize their time at home.

Interesting results published by Garver et al. (2013) involved the factors that were *not* significant in influencing retention and turnover. Previous studies identified the relationships between drivers and dispatchers, and drivers and upper management as key factors influencing turnover rate. Garver et al. (2013) concludes dispatchers have less influence on the turnover rate because most large companies now utilize automated routing and scheduling systems to determine delivery assignments. No longer are dispatchers viewed as the ones who are determining which drivers receive the more desirable and profitable runs or have influence over the length of time a driver remains at home. The absence of upper management from survey results suggests a trend of a growing social distance between top managers and truck drivers.

One of the challenges the trucking industry faces while addressing the driver shortage problem is the availability of qualified applicants. This problem largely exists because many carriers have placed a high emphasis on safety and the professionalism of their employees. As a result, carriers have become more selective in their hiring process. Costello (2017) indicates the lack of qualified applicants makes the effect of the shortage more severe than the numbers indicate because simply hiring more drivers may not be a feasible option. The issues associated with the driver shortage are expected to increase in scope and magnitude as the demand for services from the trucking industry increases and strains the existing truck driver force (Costello, 2017).

An increase in regulations makes it unlikely carriers will reduce the high level of scrutiny among truck driver applicants. While easing the requirements to be hired as a truck driver, the risks outweigh potential gains for carriers. In 2010 the FMCSA introduced Compliance, Safety, and Accountability (CSA) to monitor truck companies' adherence to federal regulations (Collins, 2013). One component of CSA is to publish truck company Behavior Analysis and Safety Improvement Categories (BASIC) scores. The BASIC score is computed by factoring in truck company data such as HOS violations, accident history, hazardous material compliance, driver health, and vehicle maintenance. Shippers commonly refer to a truck company's BASIC score when selecting a carrier to hire. Therefore, it is in the best interest of truck companies to hire the most qualified drivers in order to avoid earning a low BASIC score. According to Collins (2013), responsible motor carriers cannot tolerate substandard quality among their drivers.

A severe truck driver shortage has the potential to create significant impacts on the effectiveness of logistics operations across the U.S. The Council of Logistics Management states the purpose of logistics is to ensure the supply chain is able to meet consumer demands. This purpose is often rephrased as ensuring "the right product at the right place at the right time in the right quantity at the right cost" (Iovan, 2017). There is historical precedence that shows the impact on logistics operations caused by a major disruption to the trucking industry. Immediately following the 9/11 terrorist attacks, severe truck delays at the Canadian border forced several automobile manufacturing plants in Michigan to shut down when just-in-time parts could not be delivered (ATA, 2015). A severe truck driver shortage may result in increasing unreliability with respect to delivery schedules. This unreliability may force manufacturers and retailers to switch from just-in-time logistics strategy to a strategy of just-in-case where increased buffer stocks are stored throughout the supply chain (Fritetelli, 2016).

The impacts of a severe truck driver shortage may also extend into intermodal transportation operations. Intermodal transportation involves the combination of transportation modes to transport goods or products. The basic modes include motor, rail, water, and pipeline carriers (Leong, Tan & Wisner, 2012). One common element of intermodal transportation is the use of the motor mode, which includes the trucking industry. Oftentimes trucks are used to provide the first and last mile for intermodal moves. A disruption within the trucking industry, therefore, has the potential to create a situation where in-bound cargo sits idle at train and air terminals, and container ships remain idle at maritime ports (ATA, 2015). The potential risk to the rail industry is significant based on the amount of freight transported via the U.S. rail network. The rail industry is second only to the truck industry in terms of percentage of tonnage of freight transported. In 2016, the rail industry moved 41 percent of all freight tonnage, compared to the 42 percent of tonnage moved by the trucking industry (Fritetelli, 2016). One potential solution to the truck driver shortage rests with the application of artificial intelligence in the trucking industry.

Fourth industrial revolution

According to Dr. Klaus Schwab from the World Economic Forum, we currently live in a period known as the fourth industrial revolution (IR). Schwab (2016) explains that revolutions are periods of "abrupt and radical change" that disrupt current systems and have a profound impact on business processes and models. The fourth IR is viewed by many people as "the most important societal and economic trend in the world" that will "fundamentally change the nature of work, business, and society" (Hirschi, 2018). Some critics suggest that we have not yet entered into a new IR. Schwab (2016) counters the critics by pointing out that technological advancements today continue at an exponential rate vice a linear rate experienced in previous IRs. A review of previous IRs is useful to emphasize the existence of a new IR.

Industrial revolutions are significant because they are highlighted by the development of new technology leading to new ways of doing things and not simply increased levels of production or efficiency at lower prices. Daemmrich (2017) provides insight into the characteristics of the previous IRs. Industrial revolutions roughly encompass a 30-year timeframe of intensive change. The first IR began in the 1850s with the development of steam power that led to the mechanization of processes in areas including manufacturing, agriculture, and transportation. This IR also enabled the development of precision tooling capabilities and interchangeable parts. The second IR began around 1910 with the mass electrification of the U.S. which enabled mass production assembly lines and the development of new products such as plastics. The third IR began in the mid-1970s with the development of semiconductors that enabled the development of computers and the associated information storage and processing. The fourth IR began with the advanced development of technologies such as AI, autonomous vehicles, and quantum computing (Daemmrich, 2017). Indeed, AI is a technology currently experiencing rapid development and implementation. Chui et al. (2018) describes AI as a transformational technology with applications that are rapidly spreading throughout all aspects of the economy. However, there is not a universal agreement that we are currently in the fourth industrial revolution. Daugherty & Purdy (2016), for example, agree that AI provides growth opportunities, but suggests this technology is not transformational.

Artificial intelligence

Artificial intelligence is not a recent technology. The term “AI” was first used in 1956 by Stanford computer science professor John McCarthy. Since then, AI development has experienced periods of breakthroughs creating excitement on the technology, followed by periods of disinterest (Gesing, Michelsen & Peterson, 2018). The 1990s were one such period that led to significant breakthroughs in AI technology. One of the earliest achievements came in 1997 with the chess match victory of IBM’s computer Deep Blue over world champion Garry

Kasparov. The success for IBM continued through 2011 when their computer Watson defeated previous “Jeopardy” champions Ken Jennings and Brad Rutter (OSTP, 2011). AI technology continues to evolve and be implemented by numerous companies. Netflix, for example, uses AI to provide video streaming viewers recommended movies and programs to watch based on the viewers’ history. AI-driven viewing recommendations now account for 80 percent of all movies watched on Netflix. The online retailer Amazon also uses AI-driven product recommendations which now account for 30 percent of their total revenue (Gesing, Michelsen & Peterson, 2018).

Scientists have not established a universally accepted definition of AI. Larry Tesler, a leading computer scientist who has been developing AI technology since the 1960s describes AI as “whatever hasn’t been created yet” (Bughin et al., 2017). Gesing, Michelsen & Peterson (2018) expand on Tesler’s broad definition by writing AI is the ability of machines to exhibit human intelligence that approximates, mimics, or replicates human thinking. Furthermore, essential defining characteristics of AI are the ability for a machine to perceive, understand, learn, problem solve, and reason. A popular AI textbook offers additional definitions of AI by describing it as a system that thinks like a human, or acts like a human, or a system that acts rationally (OSTP, 2011). A common characteristic of AI, regardless of the definition being used, is the ability for a machine to solve a problem without having to rely on hand-coded software or algorithms. This ability for machines to “learn” is one of the most significant AI technological advancements (Allas et al., 2018).

Machine learning is a key driver to advancing AI technology that does not rely on algorithm programmers. Traditional machines and computing devices solve problems based on the algorithms created by a human programmer that writes software code. These algorithms are simply a set of mathematical instructions written by the programmer for how to solve a problem.

With traditional machines, the ability to solve problems is limited by the programmers' ability to write software code (Marshall, 2018). With machine learning, algorithms are still utilized, but they are generated by statistical analysis vice a human programmer. The machines analyze large amounts of data and learn from the data they have been provided without relying on the rules-based programming to draw a conclusion or to direct an action (Allas et al., 2018). Machine learning represents a breakthrough technology that enables machines to execute a statistical analysis of data, determine a rule or procedure that explains how the data was generated, and then predict future data (OSTP, 2016). Daugherty & Purdy (2016) describe these steps as sense, comprehend, and act. The end state is machines having the ability to make decisions and take actions based on a statistical analysis instead of specific instructions by a human. Machine learning technology is currently the main focus for AI research and development (R&D). Analysts at McKinsey & Company estimate that almost 60 percent of the $8-12 billion spent on AI R&D in 2016 was spent on advancing machine learning (Allas et al., 2018).

Drivers of AI development

Three key factors enabling the current wave of AI development are the availability of big data, improved machine learning, and powerful computers. Billions of gigabytes of data is generated across the globe on a daily basis (Bughin et al., 2017). The availability of big data across the world has experienced a compound annual growth rate of over 50 percent since 2010 as the number of devices connected to the internet has increased. This data is the fuel needed to drive AI development. The exponential growth of data availability provides a reliable input to feed AI improvements. As one computer scientist explained, "data is to AI what food is to humans" (Daugherty & Purdy, 2016). With this vast amount of available data, machines are able to conduct statistical analysis that generates more powerful and accurate machine-learned algorithms (OSTP, 2011). Finally, advancements in computing power and efficiency enabled the processing of massive data sets that drive AI technology. One of these advancements is the transitioning of computing machines from using a central processing unit (CPU) to a graphical processing unit (GPU). While originally designed to support computer gaming graphics, GPUs have the capacity to conduct hundreds of concurrent computing tasks, compared to the CPU that can conduct several concurrent tasks. The application of GPUs is enabling machines to process the large amounts of available data and generate the useful algorithms. Additionally, cloud computing is enabling massive data sets to be processed by powerful central computers which is aiding in AI development (Gesing, Michelsen & Peterson, 2018).

Artificial intelligence is separated between narrow AI and general AI. Much of the progress in AI has been concentrated in the field of narrow AI, which involves the execution of a specific application such as playing strategic games, language translation, and AI-driven product recommendations. Recent advancements provide an indication that narrow AI may soon serve a critical role in medical diagnosis, education, and scientific research (OSTP, 2016). General AI, or artificial general intelligence (AGI), is a technology that seeks to develop a machine that can execute *any* human task, not just specific tasks associated with narrow AI. Most AI research and development has focused on narrow AI because of its near-term business potential, as AGI is yet to be developed (Allas et al., 2018). The general consensus of private industry and the FMCSA is that AGI will not be developed within the next decades (OSTP, 2016).

When examining AI it is also important to differentiate the technology based on the level of required human interaction. Utilizing these parameters, OSTP (2016) examines the difference between autonomy and automation. In general, autonomy is used to describe the ability of a system or machine to adapt to changing circumstances with limited to no human control. In this sense the more autonomous a machine is, the more it can perceive, understand, learn, problem solve, and reason without the assistance of a human. Automation refers to a machine designed to accomplish work previously completed by a human. Automation is a phenomena that has existed since at least the first IR. While it is generally accepted AI will have an impact on the level of automation across multiple industries, there is no concurrence as to the level of automation that may occur. Gensing & Peterson (2018) predict 49 percent of all tasks currently completed by a human could be replaced by automated AI technology. Human tasks poised to be replaced are those that are highly repetitive, predictive, simple, and completed with a high frequency.

Artificial intelligence is nearing a tipping point having potential for disruptive impacts. Bughin et al. (2017) conclude successful businesses should adopt and exploit AI technology as opposed to compete against it. Their research for the McKinsey Global Institute has found evidence that suggests early adopters of AI technology in retail, utilities, manufacturing, health care, and education experienced higher profit margins than competitors that had not embraced AI. Bughin et al. (2017) predict the performance gap will continue to expand between the early AI adopters and those hesitant to embrace the technology. Research published by Accenture mirrors the optimism for the potential economic impact of AI. This research examined models of AI's impact on 12 developed economies that account for over 50 percent of the global economic output. Daugherty & Purdy (2016) explain AI has the potential to double the economic output for these 12 economies by the year 2035. However, Gensing & Peterson (2018) estimate about 9 percent of jobs currently completed by humans may be completely replaced by AI technology during this same time horizon. The report cautions against too much optimism, though, because while there is expected to be a net gain in jobs, most new jobs will be medium-skilled positions working closely with machines such as collaborative industrial robots.

Barriers

Despite the potential positive impacts, there are barriers to widespread AI implementation. The primary barriers revolve around a general lack of trust in AI technology. Gesing, Michelsen & Peterson (2018) explain that most individuals simply do not trust the application of AI in everyday life. However, their research indicates individuals typically think of AGI when asked to provide opinions on AI. This is to say most individuals fear a situation where AI overtakes human intelligence to create catastrophic implications for humanity. While the average citizen may have this fear, it is not prevalent among AI researchers. As one researcher explained, he is more worried about overpopulation on Mars than he is about AGI (Gesing, Michelsen & Peterson, 2018). Daugherty & Purdy (2016) noted a similar barrier to AI implementation in that there is currently no code of ethics for AI.

The U.S. federal government fully supports the development and implementation of AI technology. The current administration is focused on supporting AI research and eliminating barriers to innovation. President Trump’s 2019 budget is the first time in history the government has allocated money to fund AI and autonomous systems as a research and development priority. The initial budget proposal to congress states, “AI holds the potential to transform the lives of Americans” (OSTP, 2018). To help reduce barriers to innovation the National Science and Technology Council (NSTC) established the Select Committee on Artificial Intelligence. This new committee is intended to improve the overall effectiveness of AI research and development across U.S. government agencies and the private sector. The end state is that conditions are established to ensure the U.S. remains a leader in AI development. The previous presidential administration also supported AI development by promoting the potential positive economic impact on the U.S. economy. While there was an understanding AI had not yet created significant productivity growth, the administration was focused on ensuring research and development continued on the technology across the public and private sector. There was an underlying belief that AI was the lynchpin to the fourth industrial revolution (OSTP, 2016b).

III. Discussion

AI application to trucking industry

The trucking industry is one of many expected to benefit from the application of AI technology. Morgan Stanley estimates the potential value of AI automated and autonomous vehicle technology is $1.3 trillion annually (Clements & Kockelman, 2017). Current research efforts are primarily focused on applying autonomous technology to long haul trucking operations that execute inter-city and inter-state deliveries over extended distances. This is opposed to trucking operations that complete intra-city deliveries with dump trucks and cement trucks for construction projects (Frittelli, 2017). Litman (2018) adds that long haul trucking is ideal for autonomous vehicles because of high labor costs within the long haul trucking sector. Additionally, this type of trucking typically involves limited routes along mostly improved highways and roads. These relatively stable conditions are well-suited for the machine learning required of autonomous vehicles.

Development of AI assisted technology within the automotive and trucking industries has created several categories of new vehicles. The DOT uses the term “highly automated vehicle” (HAV) to describe vehicles that have Level 3 automation and higher (Table 1). Level 3 automation covers the range of vehicles that can perform some or all of the driving tasks while a human is ready to take full control, all the way to fully autonomous vehicles. With an HAV, the human driver is able to maintain full control of the vehicle, or pass control of the vehicle over to the smart systems on board. The term HAV is also used as a general term describing the desired end state for AI application to automobiles and trucks (U.S. DOT, 2016). Additional new vehicles include autonomous vehicles (AVs), and connected and highly automated or fully autonomous vehicles (CAVs). Vehicles considered AVs have on-board computers, rather than a driver, that maintain control of the vehicle at all times. These AVs operate independently while on a roadway network. Google, Apple, and Uber are currently some of the leaders in developing AV technology. CAVs are similar to AVs with the exception that CAVs are connected to each other via data links that allow them to share information. This sharing of information has the potential to generate widespread improvements in safety and time savings (Clements & Kockelman, 2017).

Table 1: Autonomous Vehicle Scale (Murray & Short, 2016)

At SAE **Level 0 (L0) No Automation:** the human driver does everything.
At SAE **Level 1 (L1) Driver Assistance:** an automated system on the vehicle can sometimes assist the human driver conduct some parts of the driving task.
At SAE **Level 2 (L2) Partial Automation:** an automated system on the vehicle can actually conduct some parts of the driving task, while the human continues to monitor the driving environment and performs the rest of the driving task.
At SAE **Level 3 (L3) Conditional Automation:** an automated system can both actually conduct some parts of the driving task and monitor the driving environment in some instances, but the human driver must be ready to take back control when the automated system requests.
At SAE **Level 4 (L4) High Automation:** an automated system can conduct the driving task and monitor the driving environment, and the human need not take back control, but the automated system can operate only in certain environments and under certain conditions.
At SAE **Level 5 (L5) Full Automation:** the automated system can perform all driving tasks, under all conditions that a human driver could perform them.

In addition to the various types of AI-enabled vehicles, there are six different levels of vehicle automation. In 2016, the USDOT adopted the Society of Automotive Engineers (SAE) levels of automation to standardize the conditions for AI application across the automotive industry. The levels range from zero to five and have an increased amount of automation as the level increases. Each level of automation has distinctions between the responsibilities of the human driver and the automated system (U.S. DOT, 2016; Table 1). Many cars today are available with options that involve L1 and L2 technology. Options such as adaptive cruise control, self parking, lane departure, and crash avoidance systems are common options for many new cars (Fagnant & Kockelman, 2015).

There are many potential benefits associated with the application of AI-enabled technologies within the trucking industry. One of the primary benefits is improved roadway safety through the reduction in accidents. A common theme associated with vehicle accidents is human error. Estimates commonly list human error as the cause of 90-94 percent of all vehicle accidents (U.S. DOT, 2016; Clements & Kockelman, 2017; Litman, 2018). Widespread use of current technology such as lane departure and crash avoidance systems, coupled with technology currently under development, has the potential to significantly reduce the quantity of accidents caused by human error. Clements & Kockelman (2017) review research indicating vehicle accidents may drop 80 percent once commercially viable L4 systems become common in cars and commercial trucks. Within the trucking industry specifically there is an average of eight deaths per day due to truck accidents (Levandowski & Ron, 2016). L4 systems have the potential to drastically reduce the number of deaths that occur with truck accidents. U.S. DOT (2016) echoes this optimism with an assessment that HAVs can mitigate the overwhelming majority of automotive and truck crashes.

Benefits of AI

There are also potential economic impacts related to the application of AI within the trucking industry. McKinsey & Company estimate that by 2025 the economic gains generated by driverless vehicles within the trucking industry may range from $100-500 billion a year (Clements & Kockelman, 2017). One source of savings will come from the reduced frequency of accidents. Additional savings will come from the increased capacity generated by 3 million truck drivers currently within the industry. Utilization of HAVs will enable the current workforce of truck drivers to complete an increased number of shipments. This increase in shipments is primarily a result of the reduced impact of HOS restrictions. HAV technology will enable truck drivers to operate much like airline pilots monitoring autonomous systems rather than directly controlling them. As a result, truck drivers will complete more shipments because time spent in the "auto-pilot" mode may not count against the daily operating limits (Frittelli, 2017). Further, employment of CAVs will facilitate the operation of convoys or "platooning" among trucks. With the platooning concept, a single truck driver can monitor a series of automated vehicles within the truck platoon. The effect will be a single driver controls multiple vehicles, increasing the delivery capacity without increasing the human labor input (Clements & Kockelman, 2017).

While AI-enabled automated vehicles may offer several benefits to the trucking industry, some analysts and industry professionals are wary of the estimates. Litman (2018) notes that many of the optimistic views of vehicle automation are generated by companies with money to gain from the new technology. It is basic economics that these estimates would highlight the significant advantages of the developing technology. Litman (2018) further clarifies that most of the predicted benefits from HAVs or CAVs require L4 or L5 vehicles. The requirement for this level of automation is troublesome given the level of automated vehicles currently available. A Congressional Research Service report states it is doubtful driverless vehicles will be feasible in the near future (Fritteli, 2017). This pessimism is mirrored by the Toyota Research Institute CEO Gill Pratt who recently stated neither the automobile nor information technology industries are close to achieving L5 autonomy (Litman, 2018). Even the American Transportation Research Institute agrees that L5 vehicles and adequate roadway infrastructure is not likely to be available commercially for "quite some time" (Murray & Short, 2016).

Automotive and truck manufacturers are fully committed to developing L5 technology. McKinsey (2016) predicts the growth in automation systems will account for over 50 percent of new revenue pools by 2025. By this same year automation features offered in commercial trucks will account for 10 percent of all truck sales revenue. Morgan Stanley (2013) assures that research efforts will lead to L5 capabilities. The report notes that the leap in technology required to develop fully autonomous vehicles is not as great as the leap that resulted in new battery technology for commercially available electric cars. The most challenging technology that needs to be developed prior to realization of L5 vehicles is machine learning for the vehicles' main computer. This is particularly because it is not possible for a human to program a vehicle for all circumstances that will arise on the road; vehicles need to be able to learn how to react to new situations (Gesing, Michelsen, & Peterson, 2018). Issues like how to handle a tire blow out or what to do when a deer runs in front of a truck are examples of situations to which autonomous vehicles need to learn how to react. Future truck designs must also adopt features currently available in cars in order to enable L5 vehicles. Common automobile features such as automatic breaking using cameras and radar to detect objects, lane departure warning systems, air disc brakes vice drum brakes, and automatic transmissions must be incorporated into truck designs (Frittelli, 2017). Clements & Kockelman (2017) note fully automated or autonomous vehicles will become a reality once these required technologies become readily available.

Legal challenges and obstacles

In additional to technological breakthroughs, there are several international and federal legal barriers that need to be resolved prior to implementation of fully automated vehicles. The 1949 United Nations (UN) Geneva Convention on Road Traffic and 1968 UN Vienna Convention on Road Traffic as written prohibit autonomous vehicles. The U.S. is a contracting party to the Geneva Convention and obligated to abide by all articles. The U.S. is only a signatory to the Vienna Convention which means the U.S. is not obligated to abide by any of the articles. In practice though, the U.S. observes all articles of the Geneva and Vienna Conventions as international common law. Article 8 of both Conventions state each vehicle shall have a driver that is able to control the vehicle at all times. Article 8 of the Vienna Convention is even more restrictive by adding that drivers must possess necessary physical and mental abilities and conditions to drive the vehicle (Acosta, 2018). Within the U.S. there are many states with laws that ban tailgating. These existing tailgating laws prohibit the use of truck platooning-one of the requirements to maximize the benefits of automated vehicles (Frittelli, 2017). Gesing, Michelsen & Peterson (2018) summarize that implementation of full autonomous vehicles without a driver in the current legal sense requires significant regulatory changes for any country planning to utilize this technology. Finally, there is currently no national framework for licensing and testing standards for automated or autonomous vehicles. States have the ability to establish their own licensing standards that may differ from neighboring states. This presents a significant challenge when conducting long haul deliveries across state lines with automated systems (Fagnant & Kockelman, 2015).

Another significant legal issue with implementation of AVs revolves around accident liability. The issue of liability is so significant that Morgan Stanley (2013) says it is the primary barrier to AV growth. Human drivers are normally not held at fault for responding to issues beyond their control, even if their actions lead to a vehicle crash. This is because crashes may be unavoidable when a driver responds to events such as a deer jumping in front of a moving car, or when a driver crosses into another lane of traffic to avoid a car that has drifted into their lane (Fagnant & Kockelman, 2015). The issue of liability becomes more complicated when a vehicle controlled by a computer is involved in an accident. In this situation it is unclear who will be liable for causing the accident. Clements & Kockelman (2017) suggest auto manufacturers and software providers will likely become the main responsible party for AV accidents. The issue of liability will require companies that manufacture or operate AVs to purchase liability insurance to cover damage caused by their vehicles (Frittelli, 2017). While it's unknown exactly who will be held responsible for AV accidents (manufacturer, truck company operating AVs, or the human driver that allows an automated vehicle to take full control of the vehicle), what is clear is courts will have to decide on the liability issue (Morgan Stanley, 2013).

One final obstacle to the implementation of automated vehicles is human acceptance of the technology. According to Morgan Stanley (2013), many consumers are reluctant to trust their lives with an autonomous system. Studies have concluded there is a divide among consumers on whether they would like to see autonomous technology available in vehicles. This divide will likely cause the mass acceptance of the technology to take a long time. Acceptance could take even longer if autonomous vehicles are involved in accidents during the early adoption stage of the technology. Even with the current reluctance to autonomous technology, Morgan Stanley (2013) expects autonomous vehicles to eventually become reliable and capable, thereby earning the confidence of the public. One demographic that has indicated acceptance for autonomous technology is Millennials. Research indicates 18-29-year-olds are more receptive to automated technology than older generations (Accenture Mobility, 2017).

Timeline

Even with the barriers to autonomous and automated vehicles, there is a potential timeline for development and implementation of fully autonomous vehicles. Litman (2018) examines the development of vehicle technology developments that are now standard features on all new cars. For example, automatic transmissions took 50 years to fully develop and airbag technology took 25 years to fully develop. Litman (2018) uses these examples to predict that L5 technology will take a long time to develop and become commercially available. The current estimate is that L5 trucks will be available between 2040-2050. However, L1-L4 enabled trucks may be available much sooner than L5 trucks. McKinsey (2016) anticipates 51 percent of all new commercial vehicles will be equipped with L4 automation by 2025. One example that reinforces McKinsey's anticipation for L4 vehicles was the October 2016 test completed by Ottomotto LLC (OTTO). During this test, OTTO completed an origin to destination delivery of 120 miles utilizing a semitruck outfitted with an aftermarket L4 autonomous system. While on the highway the driver placed the truck in autonomous mode and remained in the sleeper berth for the duration of the highway travel (Murray & Short, 2016).

While implementation of fully autonomous vehicles is decades away, the trucking industry can experience significant benefits from L1-L4 AI-enabled vehicles. Litman (2018) cites reduced truck driver stress and improved productivity for existing drivers as the primary benefits. Murray & Short (2016) concurs with this assessment and adds further explanation regarding the benefits of L1-L4 technology. L1-L3 automated trucks can help reduce stress and the monotony of long haul truck driving through the use of an automated system that can perform limited driving functions. With this level of automation truck drivers are simply monitoring the system, which requires less attention than maintaining full control of the truck. However, the driver needs to remain in the driver's seat prepared to regain full control of the truck if requested by the automated system. Even more benefits will come with utilization of L4 automation, which does not require the driver to remain in the driver's seat. With an L4 automated truck, the driver is free to complete additional tasks such as logistics coordination or rest in the sleeper berth.

Role in reducing truck driver shortage

If uncorrected, the trucking industry is on pace to experience a shortage of 175,000 drivers by 2024 (Murray & Short, 2016). Automated and autonomous vehicles provide a potential solution to this growing truck driver shortage. Trucks equipped with automated systems will assist with recruiting new drivers into the industry. Costello (2017) notes features such as driver assist technology and crash avoidance systems will have a positive impact on driver shortage because they will make the profession less stressful. Additionally, the advanced technology in future commercial trucks will attract a younger generation to trucking, a generation that is currently underrepresented in the trucking industry. Automated trucks may also encourage potential drivers of all ages to join the trucking industry because of the possibility of increased time at home. One common complaint among truck drivers is the lack of time spent at home with their families. However, widespread adoption of L4 technology has the potential for truck drivers to spend more time at home because the HOS limits will not be as restrictive. Whereas under current law, a driver must park his truck and rest in order to reset the HOS hours, L4 automation may enable truck drivers to remain in their sleeper berths while the automated system controls the truck without counting against HOS limits. The end state is truck drivers will have increased flexibility in how they manage their weekly hour limits (Murray & Short, 2016).

Automated and autonomous vehicles may also reduce the impact of the truck driver shortage by improving the productivity of existing drivers. McKinsey (2016) expects the increase in productivity will require fewer truck drivers to meet the current and future demand for trucking industry services. The report concludes L1-L3 technology will assist in recruiting and retaining drivers, but fewer overall drivers will be needed once L4-L5 technology penetrates the market. The possibility of a reduction in required truck drivers is an issue the trucking industry potentially may be forced to address in the future. If this situation occurs, the tradeoff will be those truck drivers remaining in the industry will earn higher wages relative to current wages because operating an automated truck requires a higher skill level and additional training (Clements & Kockelman, 2017).

IV. Conclusion and Recommendations

Conclusion

The trucking industry provides a critical service that facilitates the effective running of the U.S. economy. Logistics operations during World War I proved that trucks could replace horse-drawn wagons to deliver critical supplies. Following the success on the battlefield, this new form of transportation began to take hold in the U.S. Since then, the trucking industry continued to expand to the point today, where nearly three-quarters of all freight in the U.S. is transported via truck (Costello, 2017). This aptly has earned the trucking industry the moniker of the “backbone of the U.S. economy” (Bass, 2004). The significance of the trucking industry is evident every day when a consumer sees one of the 3.46 million commercial trucks on the road that keep the economy running (Murray & Short).

The trucking industry must operate within the constraints of federal and state regulations. All of these regulations are intended to keep truck drivers and other motorists safe. The HOS limit is a safety measure put in place to limit the number of hours a truck driver operates per day and per week. The intent is to ensure truck drivers receive the proper amount of rest prior to operating their trucks. A recent change to how truck drivers document their HOS now requires the use of an ELD instead of legacy paper logs. The ELDs make it more difficult for truck drivers to input false data with respect to their daily driving hours. The FMCSA views the ELD mandate as a safety measure that helps enforce HOS limits, thereby protecting motorists from tired truck drivers.

A significant issue facing the trucking industry is a shortage of truck drivers. This issue became apparent in the mid-2000s and continues to expand each year. If uncorrected, the truck driver shortage has the potential to reach 174,000 by 2026 and cause disruptions to supply chain operations (Costello, 2017). The truck driver shortage is in part due to the changing image of the trucking industry. There is a belief among many truck drivers that HOS limitations and the ELD mandate have eroded the sense of freedom once associated with life as a truck driver. Other critical factors that impact truck drivers are the amount of time spent away from home, the professional reputation of the trucking company they work for, and job safety. All of these issues have combined to create an environment that is difficult to retain current drivers and recruit new ones.

Artificial intelligence provides a possible solution for the truck driver shortage. Artificial enabled technology developed during the fourth industrial revolution is leading to the creation of automated and autonomous trucks. While fully autonomous vehicles are decades away from reality, automated systems currently under development soon may be commercially available. These automated systems have the potential to turn the role of a truck driver into one similar to a pilot where the driver simply monitors a series of systems instead of retaining complete control of the truck. There is optimism that AI-enabled trucks will reduce the level of stress for truck drivers, increase safety, and improve retention and recruiting efforts. The introduction of this technology also expands the pool of potential truck drivers to Millenials who generally are attracted to technology. In addition to assisting with staffing of truck drivers, the AI-enabled systems have the potential to increase the productivity of drivers, which may reduce the overall number required to meet current and future demand for trucking industry services.

Recommendations

The future of AI-enabled technology is exciting. Research and development efforts have only begun to determine applications for this revolutionary technology. The trucking industry is poised to utilize AI-enabled systems to reduce the impact of the driver shortage. Private industry should continue to develop automated systems until these systems become common in all new commercial trucks. The trucking industry should also continue to send the demand signal for automated systems to the technology sector. Additionally, the trucking industry should begin to market their industry as one on the leading edge of a technological frontier. This sense of excitement may help revive the spirit of freedom that once characterized the trucking industry.

Even with the introduction of AI, the trucking industry should implement a multifaceted approach to fixing the driver shortage problem. Introducing new technology to the trucking industry can be one of several lines of effort to recruit and retain truck drivers. Automated systems will likely provide significant benefits for the trucking industry in the medium (L2-L3) and long term (L4). However, the trucking industry may need to develop measures that can provide immediate and short-term benefits. Additional research should be devoted to determining means to improve driver retention and recruitment. A focus should be placed on researching Millenials' perspective on the trucking industry. As Baby Boomers continue to retire, the younger generation of the workforce maybe required to replace the retirees. Trucking companies that can develop a recruiting and retention strategy aimed at Millenials have the potential to earn a competitive advantage within the trucking industry.

Finally, the federal government should continue to support the development of AI technology. The government is critical in establishing the conditions that encourage the private sector to fund AI research and development. With regards to automated and autonomous vehicles, the federal government should establish the domestic and international legal framework for the operation of these vehicles. Domestic laws and international agreements must be updated to ensure AI-enabled vehicles are authorized to operate on the U.S. road network.

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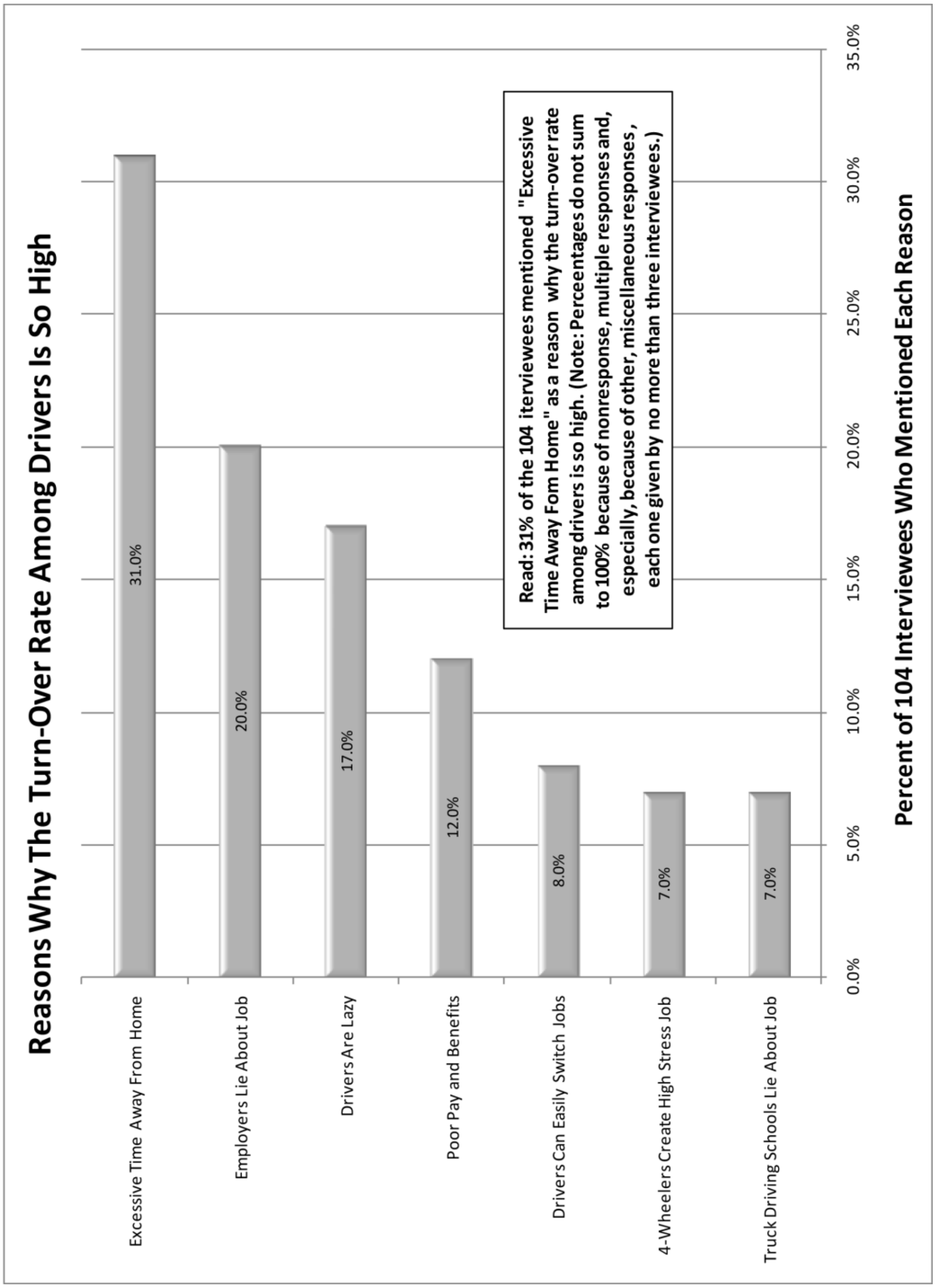
VI. Appendices

Appendix A

Category	Total	Operator Status		Marital Status		Total Years Driving	
		Company Employee	Owner Operator	Married	Single	Fifteen or Less	Sixteen or More
Fewer Federal Rules & Regulations	19%	23%	16%	11%	31%	21%	17%
More Home Time	16%	12%	20%	21%	10%	17%	15%
More Parking Spaces	10%	6%	12%	8%	12%	10%	10%
More Respected Occupation	9%	8%	9%	8%	10%	6%	12%
Less Wait Time to Load/Unload	8%	8%	7%	10%	5%	12%	4%
Better Quality Truck Stops	7%	6%	7%	5%	10%	10%	4%
Drive a New Truck	5%	6%	4%	3%	7%	2%	8%
Police Treat Us Fairly	4%	6%	2%	3%	5%	4%	4%

Source: Bristow et al., 2010

Appendix B



Source: Bristow et al., 2010