MEASURING THE IMPACTS OF COVID-19 ON THE TRUCKING INDUSTRY: A SPATIAL AND ECONOMETRIC FRAMEWORK TO CAPTURE THE IMPACTS OF THE HOURS-OF-SERVICE EMERGENCY DECLARATION AND CONGESTION EFFECTS ON TRUCK DRIVER SAFETY (PHASE 2)

FINAL PROJECT REPORT

by

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16. Abstract This project quantitatively studied the significant effects of the Coronavirus 2019 pandemic on truck drivers and the trucking industry. A stated-preference survey distributed to truck drivers collected data regarding changes in the demographic, socioeconomic, business, temporal, management, and truck configuration characteristics of the trucking industry. A total of 47 paired variables were generated from the driver survey responses. Their medians were tested for a statistically significant difference through a rank-sum procedure, through which 13 of the comparisons showed significant change during the pandemic. Of the 520 respondents, 243 (34 percent) indicated that roads were more safe during the pandemic. This study also revealed changes in trucking operations and driver behavior as a result of the relaxation of trucking hours-of-service limitations.			
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SI* (Modern Metric) Conversion Factors

APPROXIMATE CONVERSIONS TO SI UNITS				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

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List of Abbreviations

AIC:	Akaike information criterion
ATA:	American Trucking Associations
ATRI:	American Transportation Research Institute
CDL:	Commercial driver's license
CMV:	Commercial motor vehicle
COVID-19:	Coronavirus Disease 2019
DOT:	Department of Transportation
FAF:	Freight analysis framework
FHWA:	Federal Highway Administration
FMCSA:	Federal Motor Carrier Safety Administration
GPS:	Global Positioning System
HOS:	Hours of service
LHTD:	Long-haul truck drivers
MAP-21:	Moving Ahead for Progress in the 21st Century Act
NHS:	National Highway System
OOIDA:	Owner-Operator Independent Driver Association
PacTrans:	Pacific Northwest Transportation Consortium
RPBOPM:	Random-parameters bivariate ordered probit model

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CHAPTER 1. INTRODUCTION

1.1. Background

The lack of adequate truck parking along major U.S. highways is a significant problem in every state and region across the U.S. The Federal Highway Administration (FHWA), the Federal Motor Carrier Safety Administration (FMCSA), and many state departments of transportation (DOTs) have all identified the shortage of truck parking as a major nationwide issue that needs to be addressed. Numerous studies—public, private, academic, and non-profit—have been completed on the sufficiency of truck parking in the nation (Boggs et al., 2019; Bunn et al., 2019; FHWA Freight Management and Operations, 2020; FHWA Office of Operations, 2020; Hernández and Anderson, 2017; Mahmud et al., 2020; McNally, 2021). They have all found that the primary factors affecting truck parking are growth in truck activity, lack of information about truck parking capacities, and challenges due to limited delivery windows and specific rest requirements.

On the basis of the freight analysis framework (FAF) from the FHWA, freight activity in the U.S. is estimated to grow about 40 percent in tonnage in the next 30 years (FHWA Freight Management and Operations, 2017). This increase will be partially due to the convergence of advances in vehicle autonomy, manufacturing, warehousing, supply chain automation, and increases in e-commerce and the growing logistic networks being developed by large retailers such as Amazon and Walmart. Consequently, commercial motor vehicle (CMV) operators will continue to contribute to unsafe situations by driving without a required short break and/or by parking in unsafe locations such as on roadway access ramps, shoulders, highway interchanges, vacant lots, and facilities running through cities and towns.

According to the FHWA and the National Coalition on Truck Parking, there were approximately 313,000 truck parking spaces nationally in 2019—40,000 at public rest areas and

273,000 at private truck stops. Between 2014 and 2019, there was a 6 percent increase in public truck parking spaces and an 11 percent increase in private parking spaces. These findings were a part of the assessment ordered by the 2020 Jason's Law survey, which is discussed in detail later in this report. Along with this, state DOTs reported that not many new public facilities or spaces were developed and that challenges existed in planning, funding, and accommodating truck parking (FHWA Office of Operations, 2020). Most recently, the American Trucking Associations (ATA) found that there were more than 11 truck drivers for every one parking space in the nation. This survey also revealed that 98 percent of truck drivers had problems finding safe truck parking, and the average driver spent 56 minutes of available drive time every day looking for parking. That wasted time amounted to a $5,500 loss in annual compensation—or a 12 percent annual pay cut. Moreover, 58 percent of all drivers admitted to parking in unauthorized or undesignated spots at least three times per week to meet their parking needs (McNally, 2021).

The Coronavirus Disease 2019 (COVID-19) pandemic outbreak in 2020 and the restrictions implemented in response to it (e.g., stay-at-home orders, social distancing mandates), exacerbated the conditions and challenges truck drivers faced at work. Massive shortages of essential goods such as non-perishable food, cleaning products, and medical supplies created a sudden surge in consumer demand that strained supply systems for months. To support motor carriers and truck drivers involved in emergency relief efforts, federal and state government agencies instituted regulatory rule changes in trucking operations. First, the FMCSA enacted the National Emergency Declaration for commercial motor vehicles delivering essential goods (Federal Motor Carrier Safety Administration, 2020a). As a result of this change, truck drivers were no longer required to take a 30-minute break, have a regular 34-hour restart, or fulfill recordkeeping requirements. The FMCSA continued to extend and modify the exception throughout the duration of the pandemic, mostly to revise the eligible items or industries as part of the emergency list (Ahart, 2021). In June 2020, the FMCSA enacted new rules to revise four of the provisions in the old rules. The hours-of-service (HOS) were amended to provide greater flexibility for drivers without adversely affecting safety. In addition, multiple DOTs lifted restrictions on truck size and weight limits temporarily to accommodate larger shipments of goods during the pandemic (Lamb, 2020). And because many restaurants and rest areas along major routes closed, the FHWA encouraged state DOTs to temporarily waive federal regulations prohibiting commercial activities on the Interstate system to allow food trucks to operate at rest areas (Federal Highway Administration, 2020).

This study expands existing truck parking literature and continues this focus by identifying the factors that affect drivers' ability to adhere to HOS regulations during events such as pandemics and similar system disruptions. HOS requirements are typically very strict regarding the number of hours a driver can drive and the breaks that they must take to legally keep working. Drivers must maximize their productive time down to the minute to meet these specific rest requirements, in addition to any productivity expectations. This study improves our understanding of the relationship between a lack of parking and HOS adherence. The results from a stated-preference survey and the application of a random-parameters bivariate ordered probit model (RPBOPM) were utilized to determine the factors that affected drivers' ability to find adequate parking and cause HOS adherence problems before and during the pandemic. Identifying these factors sheds light on the current parking shortage and aid in the development of programs or policy initiatives to provide necessary relief for truck drivers.

CHAPTER 2. LITERATURE REVIEW

The following chapter provides details of some of the most recent policies and studies regarding truck parking. Literature related to the measured impacts of the COVID-19 pandemic are also included to provide a better understanding of the effects recognized so far.

2.1. Federal Truck Parking-Related Policy Review

Recent policies to address parking shortages throughout the national transportation network have been introduced, such as the Moving Ahead for Progress in the 21st Century Act (MAP-21), Investing in a New Vision for the Environment and Surface Transportation in America Act (INVEST in America Act), and most recently, the Truck Parking Safety Improvement Act. The following sections summarize these policies in more detail.

2.1.1. MAP-21

The Moving Ahead for Progress in the 21st Century Act (MAP-21) is a federal funding authorization bill that governs federal surface transportation spending. The bill was introduced to create a streamlined and performance-based surface transportation program that builds upon many of the already existing highway, transit, bike, and pedestrian programs. Signed into law on July 6, 2012, this bill provided over $105 billion dollars for surface transportation programs. Sections related to truck parking and freight policy are summarized in more detail in the following sections.

2.1.1.1 §1115 National Freight Policy

Section 1115 of MAP-21 establishes a national policy to improve the condition and performance of the nation’s freight infrastructure (Federal Highway Administration, 2012). This section establishes incentives to prioritize projects that advance freight performance targets, and this required USDOT, in consultation with partners and stakeholders, to develop a national freight strategic plan. States are encouraged to develop individual freight plans and establish freight advisory committees. The policy highlights goals and areas of improvement, including congestion, safety, security, resiliency, use of advanced technology, environmental impacts, and accountability in the operation and maintenance of the network. Under Section 1115, states are required to do the following:

- Establish a national freight network to assist prioritization of resources for the improvement of freight movement on highways.
- Develop a national freight strategic plan and update the plan every five years.
- Develop tools to evaluate proposed transportation projects based on performance.
- Prepare a report every two years describing the performance and condition of the national freight network.

2.1.1.2 §1401 Jason's Law

Section 1401 of MAP-21, otherwise known as Jason's Law, addresses the nation's shortage of long-term truck parking along the National Highway System (NHS). This section extends the eligibility of the National Highway Performance Program (NHPP), Surface Transportation Plan (STP), and Highway Safety Improvement Program (HSIP) to fund projects that deal with truck parking.

Under this policy, projects that are now eligible include the following:

- Construction of safety rest areas that include parking for commercial motor vehicles.
- Construction of commercial motor vehicle parking areas adjacent to commercial truck stops and travel plazas.
- Opening of existing facilities to commercial motor vehicle parking, including inspection stations, weight stations, and park-n-ride facilities.

- Promotion of the availability of publicly or privately provided commercial motor vehicle parking on the NHS using intelligent transportation systems and other means.
- Construction of turnouts along the NHS for commercial motor vehicles.
- Capital improvements to public commercial motor vehicle parking facilities, that are currently closed on a seasonal basis, to allow the facilities to remain open year-round.
- Geometric design improvements of interchanges on the NHS to improve access to parking facilities.

In addition, the USDOT was directed to establish and maintain an inventory of existing truck parking for every state, assess the volumes of commercial motor vehicles in each state, and measure the adequacy of commercial motor vehicle parking facilities in each state. The results of this evaluation must also be made available to the public.

As mentioned earlier, the 2020 Jason’s Law Survey found that there were 313,000 truck parking spaces in the U.S., with 40,000 at public rest stops and 273,000 at private rest stops (FHWA Freight Management and Operations, 2020). Public truck parking spaces increased 6 percent, while private parking spaces increased 11 percent between 2014 and 2019.

2.1.2. Truck Parking Safety Improvement Act

The Truck Parking Safety Improvement Act, introduced in the U.S. House of Representatives on March 26, 2021, is designed to facilitate access to parking around the country for commercial vehicles. The funding could be used for the construction of new truck parking facilities, expansion of truck parking at existing rest areas, conversion of space at existing weigh stations, or any other innovative solution that increases capacity as described by Congressman Mike Bost (“Bost Bill to Expand Truck Parking Would Make Roads Safer,” 2021).

2.1.3. INVEST in America Act

On July 1, 2021, the U.S. House of Representatives approved H.R. 3684, Investing in a New Vision for the Environment and Surface Transportation in America Act, or the INVEST in America Act. This bill passed as a $760 billion surface transportation and water infrastructure bill, with more than $44 billion added during the amendment process, including an amendment from Representative Bobby Rush (D-IL) that would authorize $36.6 billion over five years for electric vehicle production and deployment. The bill establishes $1 billion from the Highway Trust Fund (FY23-26) Parking for Commercial Motor Vehicles Grant Program (Section 1308) to address the shortage of parking for commercial motor vehicles to improve safety for drivers. Eligible projects include the use of intelligent transportation systems to facilitate access to publicly and privately provided commercial motor vehicle parking. Half of the program funds will be dedicated to freight-specific projects, including first-mile and last-mile delivery solutions, use of centralized delivery points, curb space management, and real-time freight parking and routing. Priority will be given to projects in areas that experience a high degree of recurrent congestion (Intelligent Transportation Society of America, 2021).

2.1.4. Hours-of-Service (HOS) Regulations

The Code of Federal Regulations, Title 49- Transportation Part 395, outlines the HOS regulations for truck drivers (Federal Motor Carrier Safety Administration, 2020b). The Federal Motor Carrier Safety Administration revised the federal HOS regulations in June 2020 to replace HOS regulations that were enacted in 2003. The HOS regulations that apply to commercial property-carrying drivers are as follows:

- 11-hour driving limit: Drivers may drive a maximum of 11 hours after 10 consecutive hours off-duty.

- 14-hour limit: Drivers may not drive beyond the 14th consecutive hour after coming on-duty following 10 consecutive hours off-duty. Off-duty time does not extend the 14-hour period.
- Rest breaks: Drivers must take a 30-minute break when they have driven for a period of eight cumulative hours without at least a 30-minute interruption. The break may be satisfied by any non-driving period of 30 consecutive minutes (i.e., on-duty not driving, off-duty, sleeping, or any combination of these taken consecutively).
- 60/70-hour on-duty limit: Drivers may not drive after 60/70 hours on duty in seven/eight consecutive days. A driver may restart a seven/eight consecutive day period after taking 34 or more consecutive hours off duty.
- Sleeper berth provision: Drivers may split their required 10-hour off-duty period, as long as one off-duty period (whether in or out of the sleeper berth) is at least two hours long and the other involves at least seven consecutive hours spent in the sleeper berth. All sleeper berth pairings MUST add up to at least 10 hours. When used together, neither time period counts against the maximum 14-hour driving window.
- Adverse driving conditions: Drivers are allowed to extend the 11-hour maximum driving limit and 14-hour driving window by up to two hours when adverse driving conditions are encountered.
- Short-haul exception: A driver is exempt from the requirements of §395.8 and §395.11 if the driver operates within a 150-air-mile radius of the normal work reporting location, and the driver does not exceed a maximum duty period of 14 hours. Drivers using the short-haul exception in §395.1(e)(1) must report and return

to the normal work reporting location within 14 consecutive hours and stay within a 150-air-mile radius of the work reporting location.

2.1.5. Transportation of Hazardous Materials

Section 49 of the Code of Federal Regulations, Part 397, specifies federal regulations for the transportation of hazardous materials (Federal Motor Carrier Safety Administration, 2020b). Trucks carrying materials that have been deemed hazardous materials are subject to more stringent parking regulations. Trucks carrying hazardous materials must not park within five feet of the traveled portion of a public roadway or highway. In addition, these trucks are not permitted to park on private property, including truck stops, without consent from the private property manager, who must be made aware of the hazardous materials being transported in the truck. These trucks also must not be located within 300 feet of bridges, tunnels, dwelling units, offices, or areas where people assemble other than for brief periods of time when it is impractical to park in any other place.

2.2. HOS Compliance-Related Studies

The degree of driver compliance to HOS regulations is of critical concern because the effectiveness of these laws is dependent on drivers actually obeying them, and those drivers who do not agree with regulations or have sufficient time pressures or economic incentives may not comply with them (Beilock, 2010; Olson, 2006). Many factors may influence drivers to find ways to circumvent these laws, including time pressures caused by limited delivery windows and specific rest requirements, and financial pressures typically exacerbated by pay structures that do not adequately compensate drivers for their work, such as pay by-the-mile, no overtime pay, and inadequate detention time pay (Beilock, 2010; Belman and Monaco, 2016; Farrell et al., 2016; Olson, 2006)

Lemke et al. (2021) performed various statistical analyses to identify factors associated with HOS compliance and to determine the significance of HOS compliance in sleep-related safety risk. The researchers used a cross-sectional survey data from 260 U.S. long-haul truck drivers (LHTD) that measured demographic, work organization, sleep health, hours-of-service compliance, and sleep-related safety performance characteristics. Longer daily work hours, lower levels of supervisor support, and failing to tell a supervisor about being too tired to drive were significant predictors of experiencing sleep-related safety risks. None of the HOS compliance variables emerged as a significant predictor of these undesirable outcomes. The authors concluded that reducing daily work hours and pace of work, strengthening driver-supervisor relationships, improving supervisor leadership and risk management techniques, making driver compensation fairer, and revisiting HOS policies may be high-leverage targets for improving regulatory compliance and safety outcomes.

Braver et al. (1992) found that 73 percent of their 1,249 surveyed tractor-trailer drivers reported violating hours-of-service rules. Thirty-one percent of the violators reported driving more than the legal limit of 60 hours in seven days or 70 hours in eight days; more than 25 percent stated that they had worked 100 hours or more per week, and 19 percent said that they had fallen asleep at the wheel at least once during the previous month while operating a tractor-trailer. The study showed that drivers violated HOS rules because of irregular route driving, low pay rates, penalties for late arrivals and delays in services, carrying perishable commodities, and being assigned unrealistic delivery deadlines. Over half of the drivers who violated the HOS regulations believed that they should be allowed to drive more than 10 hours a day and have more flexibility in their work schedules.

The bounds on the effectiveness of driver HOS regulations were investigated by Hall and Mukherjee (2008). Using data from the driving hours reported in the Fatal Analysis Reporting System (FARS)/Trucks in Fatal Accidents (TIFA) data set and from less than truckload freight companies, Hall and Mukherjee developed a crash rate function in conjunction with probability distributions to estimate reductions in crashes. They found that by constraining driving hours to a maximum of eight or nine hours, fatalities could be reduced by no more than about 3 to 5 percent. This also means that drivers could drive only two hours less than the current HOS guidelines. A 3 to 5 percent reduction in crashes would be possible only with perfect enforcement of HOS rules and an assumption that no fatalities would be transferred to shorter trips. Limiting drivers to very stringent HOS rules, such as six hours per day, would reduce the cost of crashes by about $1.2 billion per year. Previous FMCSA analyses estimated the annual cost of fatigue-related crashes to be $2.3 billion per year.

These studies have been instrumental for improving roadway safety, as they identified the effectiveness of HOS regulations, and agencies can use this information to reduce the occurrence of fatigued driving. However, although they provided useful information, little is known about the added pressures and challenges that arise during pandemics and similar system disruptions.

2.3. COVID-19 and Trucking-Related Studies

The American Transportation Research Institute (ATRI) and the Owner-Operator Independent Driver Association (OOIDA) Foundation have led research on the impacts of the COVID-19 pandemic on the trucking industry. Together they have investigated the immediate operational effects of the pandemic on trucking operations in the U.S.

In a preliminary analysis, ATRI analyzed the truck activity in California, Florida, Illinois, New York, Pennsylvania, and Washington state that took place from February 9 through April

18, 2020 (American Transportation Research Institute, 2020). As expected, the analysis of real-time truck Global Positioning System (GPS) data showed that in the early stages of the pandemic there was a spike in truck activity due to the sudden surge in demand for essential goods across the country. The analysis also reflected the impacts of implemented COVID-19 restrictions that shut down major segments of the economy. By April, trucking operations in all states had begun to decline. Among the six states, California was the first to implement a statewide stay-at-home order, and it was the first to experience an initial increase of truck activity in early March. However, the spike in activity lasted three weeks. California's trucking activity dropped 8.3 percent from February. Florida, Illinois, and New York saw spikes in truck activity the week of March 8th, but by April it had decreased by over 10 pecent from the starting point of the analysis. Similarly, truck activity in Pennsylvania and Washington suddenly increased during the week of March 15th, but it had decreased 9 percent, on average, by April. These results clearly capture pandemic's the initial impact on truck activity.

Following this preliminary analysis, ATRI and OOIDA developed a trucking industry-targeted survey to gain a better understanding of the changes in specific areas of trucking operations, including deliveries, travel times, detention, and truck parking (The American Transportation Research Institute and The OOIDA Foundation, 2020). The survey captured the assessments and perspectives of multiple trucking labor categories, from truck drivers to dispatchers to senior executives. The results showed that the impacts of COVID-19 varied significantly among trucking companies. Some fleets described steady volumes or even upticks in demand, whereas many more saw freight volumes drop abruptly. Of the 5,100 survey responses collected and deemed usable, nearly 50 percent of respondents described freight levels as "somewhat lower" to "much lower" than pre-pandemic levels, whereas 28percent reported no change, and approximately 22 percent of respondents described freight levels as being "somewhat higher" to "much higher" than normal. Further analysis of the responses provided evidence of the changes in the trucking industry as a result of the pandemic. Long-haul demand significantly decreased because of the mass reduction of container imports, and this caused a shift toward local trucking. Local trips under 100 miles more than doubled by April. Detention times were also affected: 34 percent of respondents indicated that their loading/unloading times had increased, and only 12 percent indicated that their loading/unloading times had decreased. The respondents also confirmed that the average traffic congestion delays decreased significantly; nearly 87 percent indicated that congestion was either "much shorter" or "somewhat shorter." It was also noted that discrepancies among responses for truck parking were small. Approximately 44 percent of respondents indicated that finding parking was "somewhat harder" or "much harder" to find, while slightly more than 40 percent of respondents said that truck parking was not any worse during the pandemic. Overall, the survey revealed some of the critical impacts on trucking operations from the onset of the COVID-19 pandemic.

2.4. Regulatory Rule Changes

The pandemic prompted the first significant overhaul of federal HOS regulations in over 15 years. Before the pandemic, the rules had been largely unchanged. In April 2003, the FMCSA made the first major revision. The new rules were implemented to amend several notable deficiencies in the old rules. The new HOS underwent several changes primarily designed to promote greater daily sleep and to encourage more regular daily work–rest cycles, including increased daily and weekly maximum driving limits and daily off-duty requirements (Federal Register, 2005). After that, a few changes were applied through amendments beginning on July 1, 2013. Some of these amended 2013 rules were suspended under the Consolidated and Further

Continuing Appropriations Act of 2015 (passed on December 16, 2014). These changes fine-tuned various elements of the rules, but a general underlying trend since 2005 was the FMCSA's adoption of provisions aimed at improving safety through longer continuous rest periods for truck drivers. According to the 2020 Jason's Law Survey, drivers cited two particular changes in the HOS rules in 2013 that influenced changes in truck parking characteristics across the industry. These were (1) the requirement for a continuous off-duty window under the "34-hour restart provision" to include two consecutive late-night periods of 1:00 AM to 5:00 AM; and (2) the requirement for drivers to take a 30-minute rest break during the first eight hours of a shift. Because timing for deliveries and scheduling adequate rest are critical, drivers carefully consider parking needs in planning their routes and deliveries (FHWA Freight Management and Operations, 2020).

McCartt et al. (2008) used survey-based data to assess changes in long-distance truck drivers' reported work schedules and reported fatigued driving after the new rule went into effect. A sample of long-distance truck drivers from Oregon and Pennsylvania were interviewed in three phases: immediately before the rule change (November through December 2003), about one year later (November through December 2004) and then two years after the change (November through December 2005). According to the survey, drivers drove substantially more hours after the rule change as a result of more drivers regularly using the new restart provision, which allows a substantial increase in weekly driving. The survey also revealed that the frequencies of reported fatigued driving under the old and new rules were similar. Between 2003 and 2004, before the rule change, reported incidents of falling asleep at the wheel of the truck increased. The same trend was noticed after the rule change, between 2004 and 2005, suggesting that the rule change may have not been successful in reducing fatigued driving. In 2005, 20 percent of drivers reported falling asleep at the wheel within the past month. It is important to note the survey was conducted during one of the busiest months of the year for truck drivers. When drivers were asked about delivery schedules, less than one out two truck drivers reported that they were always realistic. Truck drivers who reported that they were sometimes or often given unrealistic delivery schedules were approximately three times more likely to violate the work rules than drivers who rarely or never had to deal with unrealistic delivery schedules.

2.5. Summary of Literature Review

Overall, the reviewed literature confirmed that there are significant shortages in truck parking across the nation. Jason's Law shows that these shortages have affected highway safety. And when faced with the growing demands of the pandemic, drivers and their companies felt pressure to pivot from regular operations and quickly adapt to new ways to meet their delivery schedules. Therefore, research is needed to understand the relationship between the adherence to HOS limitations and the truck parking shortage, and the factors that affect drivers' ability to find available safe parking. This will help in the development of practical solutions that may reduce the safety risk posed by fatigued truck drivers.

CHAPTER 3. DATA DESCRIPTION

This study utilized a stated preference survey of truck drivers administered nationally during the COVID-19 pandemic. The intent of this survey was to understand truck drivers' opinions about trucking driving operations before and during the pandemic and to determine factors that potentially affect drivers' ability to find available safe parking while adhering to HOS limitations. The survey was conducted between May 25and June 1, 2020, through the University of Arkansas and was distributed to drivers of large trucks by using Qualtrics, an online electronic survey instrument. Completing the survey was voluntary, but to participate respondents had to be at least 18 years of age, hold a commercial driver's license (CDL), and have been operating their commercial motor vehicle for more than a year and also during the COVID-19 pandemic. A total of 521 truck drivers met the survey requirements and completed the survey.

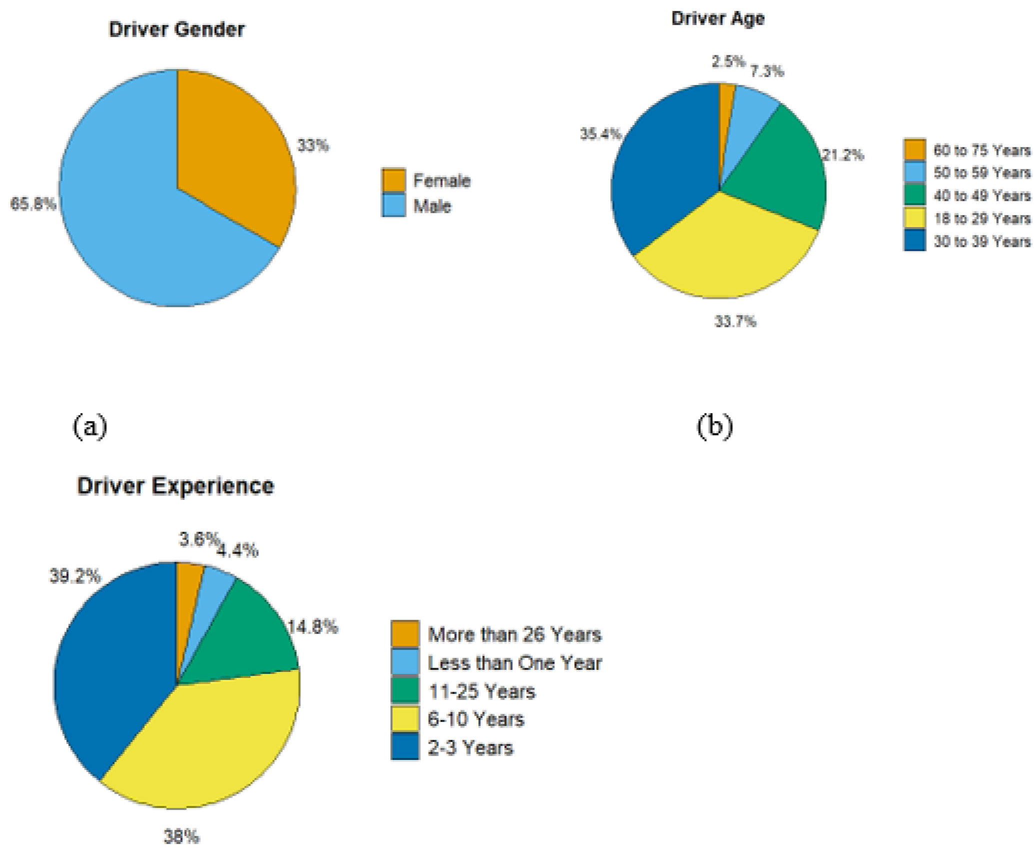
The survey included 67 questions divided into nine parts: socioeconomic, business, driver, driving characteristics, safety perceptions, time of day operations, driving management, and truck configuration. The questions regarding changes between before and during the pandemic were asked on a Likert scale to capture a holistic view of the drivers' opinions. Table 3.1 presents a summary of the joint distribution of the frequencies of the lack of available parking causing problems with drivers adhering to HOS limitations before and during the pandemic. Note that the proportion of drivers who never experienced issues finding parking was twice as large during the pandemic than before. Still, 85.4 percent of drivers reported having problems adhering to HOS limitations at least some times during the pandemic.

Table 3.1: Summary of the Frequencies of a Lack of Available Parking Causing Problems with Drivers Adhering to HOS Limitations

The frequency of lack of available parking causing problems with adhering to HOS limitations **before** the pandemic	The frequency of lack of available parking causing problems with adhering to HOS limitations **during** the pandemic					Total
	Never	Sometimes	About half the time	Most of the time	Always	
Never	30	3	3	1	1	38 (7.3%)
Sometimes	33	53	13	10	2	111 (21.3%)
About half the time	5	31	60	41	7	144 (27.7%)
Most of the time	4	22	39	51	15	131 (25.1%)
Always	4	5	12	18	58	97 (18.6%)
Total	76 (14.6%)	114 (21.9%)	127 (24.2%)	121 (23.3%)	83 (16.0%)	521 (100%)

A large number of explanatory variables were examined, and possible related variables are illustrated in the figures below to provide an understanding of the differences and similarities among the two cases.

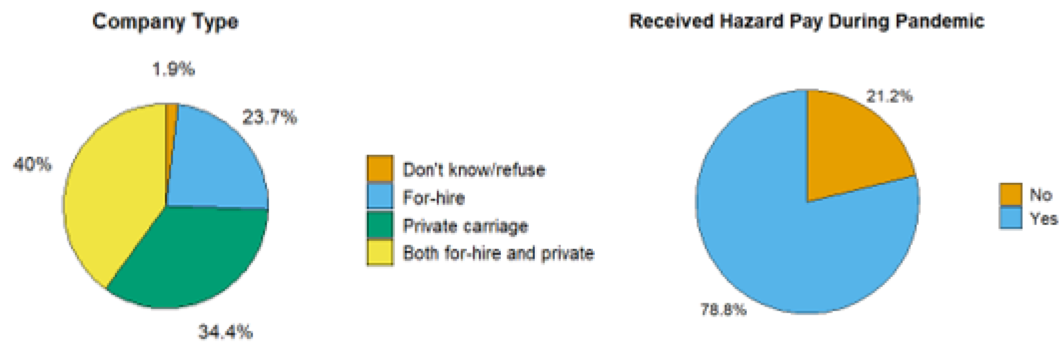
Socioeconomic characteristics were analyzed first to determine the common traits among the surveyed drivers. Figure 3.1 displays driver gender, age, and experience driving a CMV. is the figure shows that two-thirds of the respondents were male. Figure 1b reveals that nearly 70 percent of the surveyed drivers were under the age of 40; 33.7 percent were from 18 to 29 years old, and 35.4 percent were from 30 to 39 years old. Figure 1c shows that approximately 39 percent of the surveyed drivers had between two and three years of experience driving a truck, while 36 percent had six to ten years.



(c)

Figure 3.1: Driver Characteristics by Driver: (a) Gender (b) Age (c) Experience

Next, business characteristics were analyzed to gain a better understanding of the industries represented. As shown in Figure 3.2, 40 percent of the respondents worked both for-hire and for private companies, 34.4 percent worked for private carriage, and 23.7 percent worked for-hire. Also, the majority of drivers, nearly 79 percent, reported receiving hazard pay during the pandemic.



(a) (b)

Figure 3.2: Company Characteristics by (a) Company Type Driver Works for (b) Hazard Pay

Figure 3.3 displays the surveyed drivers' perceived changes in various aspects of the trucking industry. For 12 of the 13 characteristics, most drivers reported a change in operations as a result of the pandemic. The category of restrictions on the hours worked per day was the only one in which most drivers saw no change during the pandemic. This was a reflection of the relaxation of HOS for truck drivers.

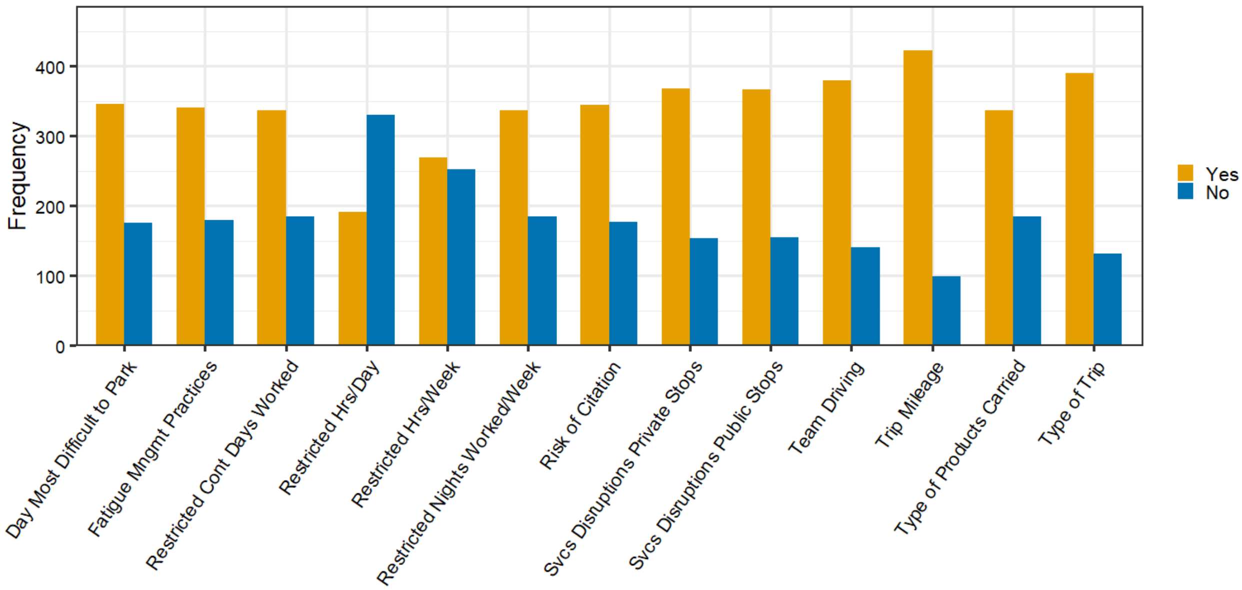


Figure 3.3: Changes in Operations as a Result of COVID-19

In relation to truck parking, various questions were asked. First, drivers were asked about how they decided where to park. Figure 3.4 shows that slightly more than a quarter of the surveyed drivers had the decision made for them by their company. Furthermore, the majority of drivers reported using some sort of real-time parking availability tools to search for parking. A mobile phone application and highway message signs were among the most commonly used tools, as shown in Figure 3.5.

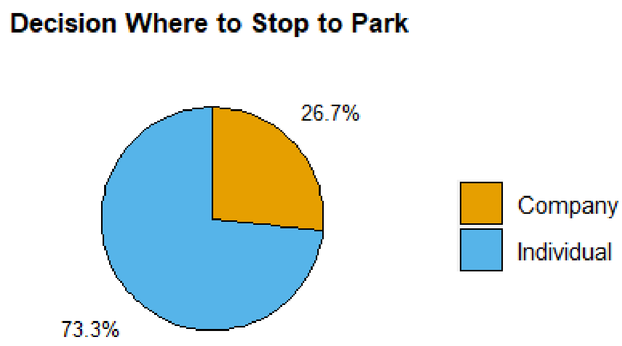


Figure 3.4: Decisions About Where to Stop to Park

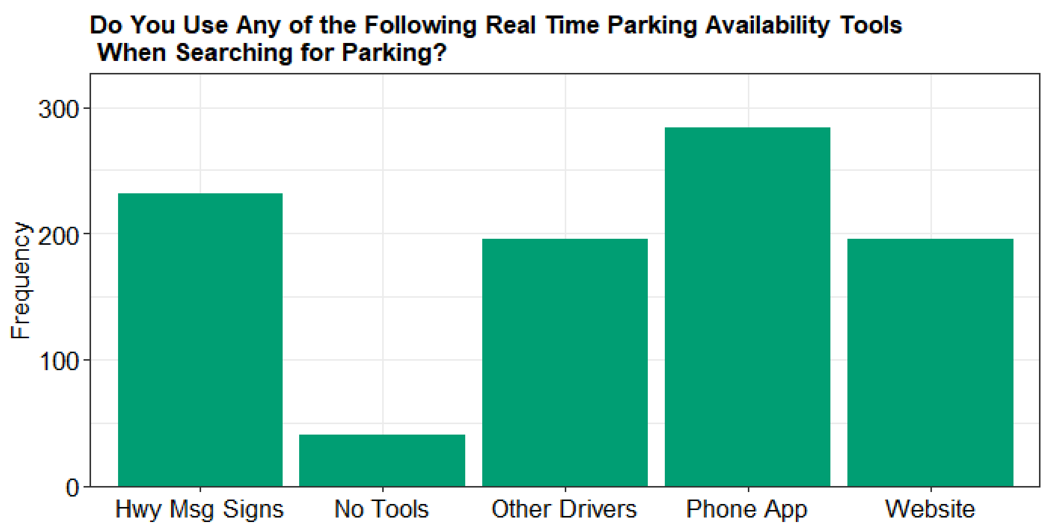


Figure 3.5: Do You Use Any of the Following Real-Time Parking Availability Tools When Searching for Parking?

Drivers were also asked about their experiences in the search for parking. Overall, drivers reported having less difficulty locating safe parking during the pandemic. Figures 3.6 and 3.7 display the breakdown in days and times. Most drivers agreed that Friday was the most difficult day of the week to secure parking. Drivers reported mid-day as the most difficult time of day to find safe parking, but mornings and afternoons appeared to also present significant issues both before and during the pandemic.

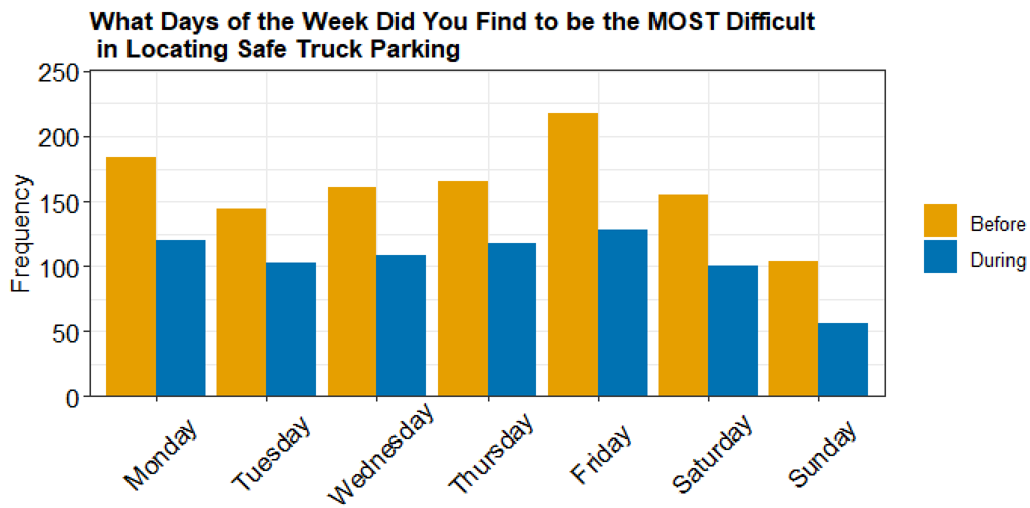


Figure 3.6: What Days of the Week Did You Find to be the Most Difficult for Locating Safe Truck Parking?

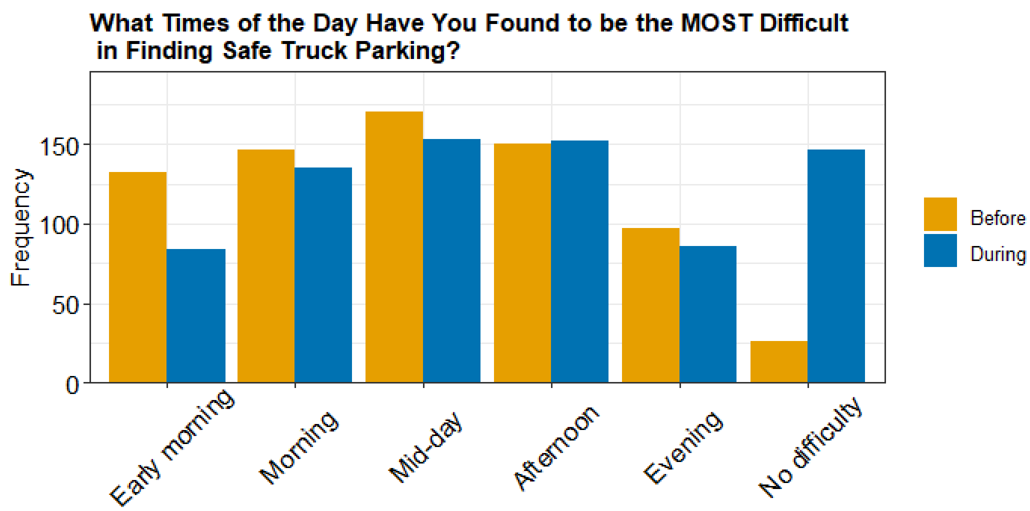


Figure 3.7: What Times of the Day Have You Found to be the Most Difficult for Finding Safe Truck Parking?

If a driver was unable to find legal parking, he or she was in a very precarious position, forced to either speed, operate illegally, or park illegally. To gain an understanding of drivers' risk aversion on the road, they were asked to indicate their willingness to take certain risks on a scale of 0 to 10, with 0 being “completely unwilling” and 10 being “very willing.” Figure 3.8 shows that approximately a third of drivers were willing to drive up to 10 miles per hour (MPH) over the speed limit. The distribution in choices was also skewed left, indicating that most drivers were more than willing to risk speeding. Similarly, Figure 3.9 reveals that nearly 30 percent of drivers were willing to drive past HOS limits. The distribution in choices was also skewed left; however, it was bimodal, with two separated classes at the high end representing the maximum frequency. In contrast, the distribution of the willingness to park illegally was heavily skewed right, meaning that drivers were hesitant about parking illegally. Still, 23 percent of drivers admitted to being willing to park illegally (Figure 3.10).

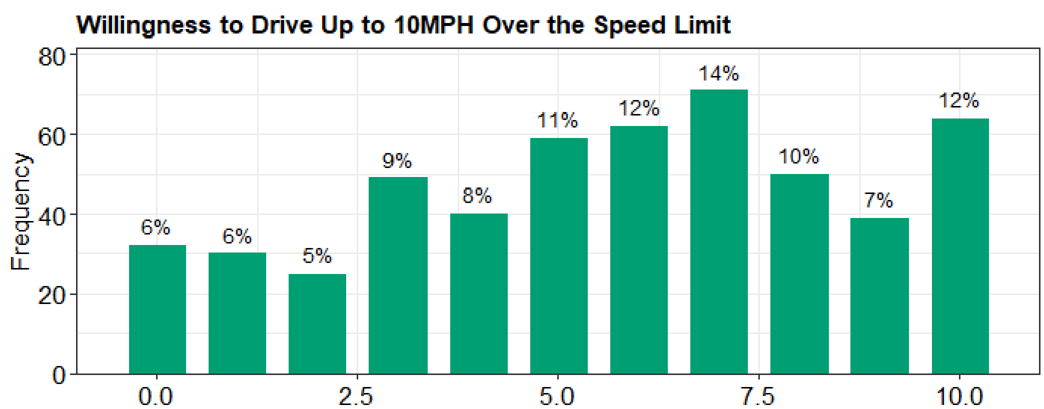


Figure 3.8: Willingness to Drive Up to 10 MPH Over the Posted Speed Limit

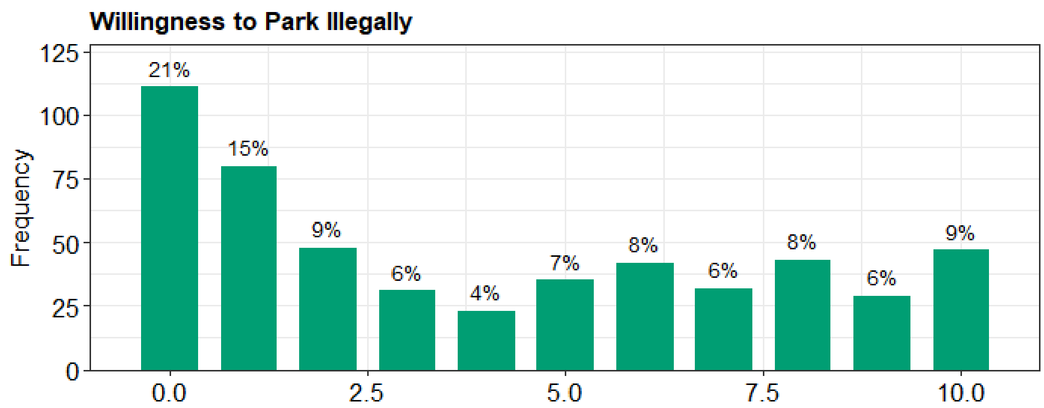


Figure 3.9: Willingness to Drive Past HOS Limits

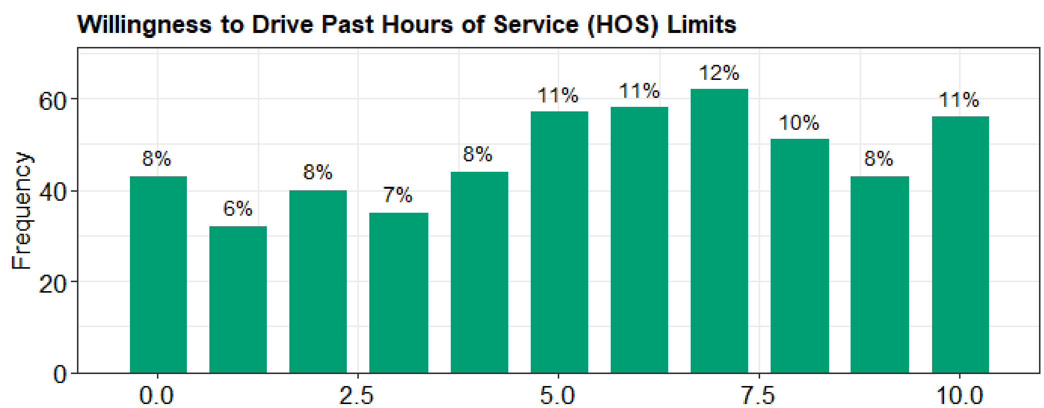


Figure 3.10: Willingness to Park Illegally

Using a stated-preference survey, various demographic, temporal, and management characteristics related to parking availability and HOS adherence during the pandemic were determined. The proportion of drivers that never experienced issues finding parking was twice as large during the pandemic than before. Still, 85.4 percent of drivers reported having problems adhering to HOS limitations at least some times during the pandemic. More specifically, drivers reported that mid-day and Friday were the most difficult time and day of the week, respectively, to secure parking. The majority of drivers adapted to these challenges by using real-time parking availability tools such as a mobile phone app or highway message signs, but one in four drivers admitted that they were willing to park illegally.

These survey results provided a better understanding of current truck parking issues, as well as shed light on the impact of the pandemic on supply chains and trucking operations.

CHAPTER 4. METHODOLOGY

To consider the issue of heterogeneity in responses from individuals for both conditions of the pandemic, this study used a bivariate random parameter ordered probit model, which is a hierarchical system of two equations that can be employed to model a simultaneous relationship of two response variables. With this, the significant influencing factors could be identified, and their impacts on the frequency of lack of parking could be quantified (Xiao et al., 2021).

The bivariate random-parameter ordered probit model assumes that two ordered dependent variables Y_j (j = 1 before pandemic, 2 during pandemic) are the outcome of a joint decision, while the decisions depend on individual characteristics of each probit equation, and the two equations' errors are correlated. Thus, the model can be described as follows (Xiao et al., 2021):

$$y_{i,j=1} = k,\ if\ \mu_{j=1,\ k-1} < y^*_{i,\ j=1} < \mu_{j=1,\ k} \qquad \text{Eq. (4-1)}$$

$$y_{i,j=2} = 1, \qquad if\ \mu_{j=2,\ l-1} < y^*_{i,\ j=2} < \mu_{j=2,\ l}$$

where $\mu_{j,k-1}$, $\mu_{j=1,k}$, $\mu_{j,l-1}$, $\mu_{j,l}$ are thresholds or cut-off values used to determine the reported frequency of a lack of parking causing HOS adherence problems before and during the pandemic; their values are relative to their corresponding influencing factors in driver *i*. Additionally, *k* (*k* = 0, 1, 2,..., *K*) and *l* (*l* = 0, 1, 2,..., *L*) represent ordinal categories of the frequency of a lack of parking causing HOS adherence problems reported by each driver. $y^*_{i,\ j=1}$ and $y^*_{i,\ j=2}$ could be calculated using real data as follows:

$$y^*_{i,\ j=1} = \beta'_1 X_{i,j=1} + \varepsilon_{i,j=1} \qquad \text{Eq. (4-2)}$$

$$y^*_{i,\ j=2} = \beta'_2 X_{i,j=2} + \varepsilon_{i,j=2}$$

where $y^*_{i,\ j=1}$ represents latent variables denoting a threshold for choosing one alternative to the other, in which *i* = *1,...n*, is the number of observations; $X_{i,j}$ represents individual specific covariates; β_j denotes the regression coefficients, and $\varepsilon_{i,j}$ represents the random components that capture all unobserved factors associated with two involved parties, which is assumed to follow a bivariate normal distribution as follows (Chen et al., 2019):

$$\begin{pmatrix}\varepsilon_{i,j=1}\\ \varepsilon_{i,j=2}\end{pmatrix} \sim \mathrm{N}\left[\begin{pmatrix}0\\0\end{pmatrix}, \begin{pmatrix}1 & \rho\\ \rho & 1\end{pmatrix}\right]$$

where ρ is the estimated correlation parameter between $\varepsilon_{i,j=1}$ and $\varepsilon_{i,j=2}$. Therefore, y_{i1}^* and y_{i2}^* denote the frequency of a lack of parking causing HOS adherence problems for drivers before and during the pandemic, respectively, and x_{i1} and x_{i2} include various influencing factors, such as socioeconomic, business, and driver characteristics captured in the survey.

The observed ordered dependent variable follows the rule with the following equation:

$$Y_{ij} = \begin{cases} 0\ if\ y_{ij}^* = Never \\ 1\ if\ y_{ij}^* = Sometimes \\ 2\ if\ y_{ij}^* = About\ half\ the\ time \\ 3\ if\ y_{ij}^* = Most\ of\ the\ time \\ 4\ if\ y_{ij}^* = Always \end{cases} \qquad \text{Eq. (4-3)}$$

While the bivariate ordered probit model can address the problem of factors correlation between two conditions, this method assumes the parameters β_1', β_2' to have a certain value, neglecting the effect of unobserved heterogeneity of observations. As previously stated, the random-parameter method can address the unobserved heterogeneity by allowing the parameters to vary across observations. Therefore, the random parameters bivariate ordered probit model can be derived by setting:

$$\beta_i' = \beta + \gamma_i \qquad \text{Eq. (4-4)}$$

where β_i' is the vector of specific parameters and is estimated by the maximum likelihood method with Halton; γ_i is the randomly distributed term that is normally distributed with a zero mean value and variance σ^2.

CHAPTER 5. FINDINGS

5.1. Parameter Models

A bivariate random parameter ordered probit model was used to identify the significant factors that influence drivers' ability to find adequate and safe parking during events such as pandemics and similar system disruptions. The models were estimated on the basis of five possible outcomes (never, around half the time, sometimes, most of the time, always), with 28 variables found to be statistically significant at the 10 percent level. A summary of the significant parameters is in Table 5.1, including a description of each.

Table 5.1: Summary of Parameters

Variable	Description	Frequency	Percentage
Before Pandemic			
Socioeconomic Characteristics			
YOUNG	Driver age (1 if between 30 and 49, 0 otherwise)	1.78	0.076
HZPAY	Compensation (1 if received hazard pay, 0 otherwise)	3.50	0.001
YRORLESS	Driver experience (1 if less than one year, 0 otherwise)	-1.95	0.051
Business Characteristics			
FEWRTRPS	Trips conducted (1 if completed fewer number of trips during pandemic than before, 0 otherwise)	-2.63	0.009
Driver Characteristics			
B_NVRTMD	Participation in team driving (1 if never, 0 otherwise)	-4.76	0.000
B_SMTMDR	Participation in team driving (1 if sometimes, 0 otherwise)	-3.76	0.000
B_HFTMDR	Participation in team driving (1 if about half the time, 0 otherwise)	-2.42	0.015
B_MSTMDR	Participation in team driving (1 if most of the time, 0 otherwise)	-3.15	0.002
Time of Day Operations			
B_PRKEM	Most difficult time of day to locate safe truck parking (1 if early morning, 0 otherwise)	3.21	0.001
B_DYMN	Most difficult day of the week to locate safe truck parking (1 if Monday, 0 otherwise)	3.03	0.002

Variable	Description	Frequency	Percentage
B_VDSVM	Service disruptions encountered at private truck stops (1 if vending machine access and supply, 0 otherwise)	3.39	0.001
B_VDSFC	Service disruptions encountered at private truck stops (1 if facility closed, 0 otherwise)	-2.51	0.012
B_VDSOT	Service disruptions encountered at private truck stops (1 if other, 0 otherwise)	-3.49	0.001
B_VDPFL	Service disruptions encountered at public truck stops (1 if fuel services, 0 otherwise)	2.95	0.003
B_VDPVM	Service disruptions encountered at public truck stops (1 if vending machine access and supply, 0 otherwise)	2.22	0.026
B_VDPRT	Service disruptions encountered at public truck stops (1 if restrooms, 0 otherwise)	-2.63	0.009
Driving Management			
RLTMPKCB	Real time parking availability tools used (1 if communications with other drivers, 0 otherwise)	-2.29	0.022
RLTMPKNO	Real time parking availability tools used (1 if none, 0 otherwise)	-2.66	0.008
B_TRDRVR	Drive while tired (1 if rarely, 0 otherwise)	-2.84	0.005
B_TRDRVN	Drive while tired (1 if never, 0 otherwise)	-4.53	0.000
Truck Configuration			
SNGLUNIT	Driver's most commonly driven truck configuration (1 if single unit truck, 0 otherwise)	2.15	0.032
During Pandemic			
Socioeconomic Characteristics			
MALE	Driver gender (1 if male, 0 otherwise)	2.33	0.020
Driver Characteristics			
D_SMTMDR	Participation in team driving (1 if sometimes, 0 otherwise)	-3.53	0.000
D_NVRTMD	Participation in team driving (1 if never, 0 otherwise)	-4.66	0.000
Time of Day Operations			
D_MDAY	Normal driving start time (1 if morning, 0 otherwise)	1.78	0.075
D_MDAY	Normal driving start time (1 if morning, 0 otherwise)	3.54	0.000

Variable	Description	Frequency	Percentage
D_DYMN	Most difficult day of the week to locate safe truck parking (1 if Monday, 0 otherwise)	2.24	0.025
D_VDPVM	Service disruptions encountered at public truck stops (1 if vending machine access and supply, 0 otherwise)	1.94	0.052
D_VDPTO	Service disruptions encountered at public truck stops (1 if take out and/or drive thru food services, 0 otherwise)	-2.35	0.019
D_VDSVM	Service disruptions encountered at private truck stops (1 if vending machine access and supply, 0 otherwise)	-1.90	0.058
D_VDSSH	Service disruptions encountered at private truck stops (1 if showers, 0 otherwise)	1.92	0.055
D_VDSTW	Service disruptions encountered at private truck stops (1 if truck wash stations, 0 otherwise)	-4.07	0.000
D_VDSFC	Service disruptions encountered at private truck stops (1 if facility closed, 0 otherwise)	1.98	0.048
Driving Management			
D_TRDRVV	Drive while tired (1 if very often, 0 otherwise)	2.80	0.005
RLTMPKWB	Real time parking availability tools used (1 if websites, 0 otherwise)	2.46	0.013
RLTMPKNO	Real time parking availability tools used (1 if none, 0 otherwise)	-2.23	0.026

The overall model fit was tested by using the chi-square distribution and Akaike information criterion (AIC), which were calculated by using Eq. (5-1), in which the likelihood ratio tests were conducted to statistically assess whether these models on the frequency of a lack of parking were significantly different across the fixed-parameter model and the random-parameter model:

$$X^2 = 2\left[LL\,(\beta_{random}) - LL\,(\beta_{fixed})\right], \qquad \text{Eq. (5-1)}$$

$$AIC = 2k - 2\ln(L)$$

where LL(β_{random}) is the log-likelihood at convergence of the random-parameter ordered probit model, and $LL\ (\beta_{fixed})$ is the log-likelihood at convergence of the fixed parameter ordered probit model. The likelihood ratio is chi-square distributed with degrees of freedom equal to the difference in the number of parameters of both of the models. *K* is the number of parameters of the model. The smaller the AIC and the higher the chi-square values, the better the model fits the data.

Table 5.2 presents the results of the random parameters bivariate ordered probit models. There were variables in the model that were normally distributed random parameters, which explicitly demonstrated the existence of heterogeneity in the effects of influencing factors. The following subsections describe the changes in the trucking industry found to be most influential on the frequency of a lack of parking causing HOS adherence problems.

Table 5.2: Results of Random-Parameter Bivariate Ordered Probit Models

Variable	Mean	Standard error	Z	Prob. Z > Z*	Prob. ≤ 0) (%)	Prob. > 0 (%)
Before Pandemic						
Constant	2.067***	0.246	8.39	0.000	0.0%	100.0%
YOUNG	0.179*	0.100	1.78	0.076	3.7%	96.3%
HZPAY	0.438***	0.125	3.50	0.001	0.0%	100.0%
YRORLESS	-0.458*	0.234	-1.95	0.051	97.5%	2.5%
B_NVRTMD	-1.070***	0.225	-4.76	0.000	100.0%	0.0%
B_PRKEM	0.371***	0.116	3.21	0.001	0.1%	99.9%
▲B_DYMN	0.329***	0.108	3.03	0.002	0.1%	99.9%
▲*B_SMTMDR*	-0.742***	0.197	-3.76	0.000	100.0%	0.0%
B_MSTMDR	-0.541**	0.224	-2.42	0.015	99.2%	0.8%
B_HFTMDR	-0.646***	0.205	-3.15	0.002	99.9%	0.1%
FEWRTRPS	-0.275***	0.105	-2.63	0.009	99.6%	0.4%

Variable	Mean	Standard error	Z	Prob. Z > Z*	Prob. ≤ 0) (%)	Prob. > 0 (%)
▲*B_VDSVM*	0.397***	0.117	3.39	0.001	0.0%	100.0%
▲*B_VDSFC*	-0.354**	0.141	-2.51	0.012	99.4%	0.6%
▲B_VDSOT	-0.910***	0.261	-3.49	0.001	100.0%	0.0%
B_VDPFL	0.332***	0.112	2.95	0.003	0.2%	99.8%
▲B_VDPVM	0.261**	0.117	2.22	0.026	1.3%	98.7%
B_VDPRT	-0.277***	0.105	-2.63	0.009	99.6%	0.4%
▲RLTMPKCB	-0.243**	0.106	-2.29	0.022	98.9%	1.1%
▲*RLTMPKNO*	-0.532***	0.200	-2.66	0.008	99.6%	0.4%
B_TRDRVR	-0.375***	0.132	-2.84	0.005	99.8%	0.2%
B_TRDRVN	-0.900***	0.199	-4.53	0.000	100.0%	0.0%
SNGLUNIT	0.219**	0.102	2.15	0.032	1.6%	98.4%
μ_1	1.105***	0.065	16.98	0.000	-	-
μ_2	2.043***	0.062	32.76	0.000	-	-
μ_3	2.996***	0.081	37.05	0.000	-	-
During Pandemic						
Constant	1.666***	0.206	8.09	0.000	0.0%	100.0%
MALE	0.366**	0.157	2.33	0.020	1.0%	99.0%
▲*D_SMTMDR*	-0.563***	0.160	-3.53	0.000	100.0%	0.0%
▲*D_NVRTMD*	-1.034***	0.222	-4.66	0.000	100.0%	0.0%
▲*D_DYMN*	0.551***	0.156	3.54	0.000	0.0%	100.0%
D_TRDRVV	0.521***	0.186	2.80	0.005	0.3%	99.7%
▲*D_VDPVM*	0.378**	0.169	2.24	0.025	1.3%	98.7%
D_VDPTO	0.296*	0.152	1.94	0.052	2.6%	97.4%
▲D_VDSVM	-0.384**	0.163	-2.35	0.019	99.1%	0.9%
D_VDSSH	-0.286*	0.151	-1.90	0.058	97.1%	2.9%
D_VDSTW	0.318*	0.167	1.92	0.055	2.8%	97.2%
▲*D_VDSFC*	-0.878***	0.216	-4.07	0.000	100.0%	0.0%

Variable	Mean	Standard error	Z	Prob. Z > Z*	Prob. ≤ 0) (%)	Prob. > 0 (%)
▲D_VDSOT	1.446**	0.732	1.98	0.048	2.4%	97.6%
▲RLTMPKWB	0.373**	0.151	2.46	0.013	0.7%	99.3%
▲RLTMPKNO	-0.951**	0.428	-2.23	0.026	98.7%	1.3%
D_MDAY	0.293*	0.165	1.78	0.075	3.8%	96.2%
μ_1	0.989***	0.100	9.91	0.000		
μ_2	1.909***	0.089	21.51	0.000		
μ_3	2.891***	0.108	26.72	0.000		
ρ (correlation parameter)	0.475***	0.076	5.42	0.000	-	-
Final Log-likelihood	-578.483					

Note. The italicized ones represent estimates for the variables resulting in random parameters. *P < 0.1, ** P < 0.05.
▲ means this variable is significant in both conditions.

5.2. Influencing Factors

5.2.1. Socioeconomic Characteristics

As illustrated in Table 5.2, before the pandemic, the frequency of a lack of parking causing HOS adherence issues was higher for young drivers, between the ages of 30 and 49, than for other drivers. The parameter of this variable was normally distributed, with a mean of 0.179 and a standard deviation of 0.100, meaning that 96.3 percent of young drivers tended to have more issues in adhering to HOS regulations as a result of limited parking. Given that they made up 56.6 percent of the surveyed drivers, and the national median age of truck drivers is 46, this does raise some concern (Cheeseman Day and Hait, 2019). At the same time, drivers with less than one year of experience had fewer issues in adhering to HOS limits as a result of a lack of parking before the pandemic. Various underlying factors may have been related to this effect, such as the use of real-time parking availability tools and who makes the decision of where to park.

The frequency of a lack of parking causing HOS adherence issues was also higher for drivers who received hazard pay versus those who did not. In other words, drivers involved in emergency relief efforts experienced more trouble finding adequate parking before the pandemic. This may have been correlated with the decrease in freight movement for certain industries as a result in the drop in demand from many retailers, manufacturers, restaurants, and other businesses across the country that temporarily slowed or shut down production. The Bureau of Labor Statistics reported that 140,000 truck drivers had lost their jobs as of December 2020 (U.S. Bureau of Labor Statistics, 2020). In addition, the survey administered by ATRI and OOIDA confirmed that the average traffic congestion delays decreased significantly during the pandemic; nearly 87 percent of the respondents indicated that congestion was either "much shorter" or "somewhat shorter" (The American Transportation Research Institute and The OOIDA Foundation, 2020).

In addition, male drivers managed a higher frequency of issues in finding adequate parking after the pandemic. Approximately two-thirds of the surveyed drivers were estimated to experience issues.

5.2.2. Business Characteristics

In regard to business characteristics, the only factor that had a significant effect was taking a fewer number of trips during the pandemic than before. Inherently, the frequency of a lack of parking causing HOS adherence issues was lower for drivers who took fewer trips.

5.2.3. Driver Characteristics

With negative coefficient values, the frequency of a lack of parking causing HOS adherence issues tended to decrease with participation in team driving before and during the pandemic. Drivers who drove in teams most of the time had the least frequency of issues, with slightly less than 1 percent of drivers reporting problems adhering to HOS limits. Teams were more efficient in working together to locate adequate parking.

5.2.4. Time of Day Operations

Time-of-day-related factors were the most influential on the frequency of a lack of parking causing HOS adherence issues, both before and during the pandemic. Monday, which was reported to be one of the most difficult days to locate adequate parking, tended to experience an increase in the frequency of parking shortages causing HOS adherence issues.

Additionally, the normal drive start time of mid-day also presented an increase in the frequency of a lack of parking causing HOS adherence issues during the pandemic. At the same time, during the pandemic 34 percent fewer drivers reported that they started driving in the morning, while 50 percent more started driving mid-day, and 140 percent more started in the afternoon. The significant changes in driving start time were likely correlated with decreases in passenger vehicle traffic and congestion levels, which was supported by the findings from the ATRI and OOIDA survey (The American Transportation Research Institute and The OOIDA Foundation, 2020). The change in start time could also have been related to the surge in demand for essential goods at grocery stores. Deliveries are usually made early in the morning or at night when most grocery stores restock their shelves.

Certainly factors related to the closures of private and public rest facilities were found to be significant. Regarding private truck stops, a closed facility and/or those offering “other” amenities decreased the frequency of a lack of parking causing HOS adherence issues, both before and during the pandemic. During the pandemic, the frequency of a lack of parking causing HOS adherence issues was significantly affected by access to showers and truck wash stations at private facilities. Shower access decreased the frequency of experiencing HOS adherence issues, whereas truck wash stations were associated with an increased probability. Various websites offer real-time truck parking availability information, indicating the locations of certain amenities including truck washes, restaurants, and repair shops. This information may influence the popularity of particular truck stops. On the other hand, truck stop restrooms at public facilities were associated with a decreased frequency of a lack of parking causing HOS adherence issues before the pandemic, whereas fuel services and vending machine access and supply were associated with an increase. During the pandemic, vending machine access continued to increase it, and so did the availability of food services.

Figure 5.1 illustrates the perceived disruption of closing facilities among the surveyed drivers. Regarding private truck stops, 13 percent of drivers agreed that there was an effect from closed facilities before the pandemic. Once the COVID-19 restrictions had been implemented, that percentage of drivers increased to 19 percent, approximately a 66 percent difference. Similarly, 15 pecent of respondents reported an impact from closed facilities before the pandemic, and this increased to approximately 33 percent during the pandemic.

5.2.5. *Driving Management*

Regarding the parameters of driving management, communication with other drivers

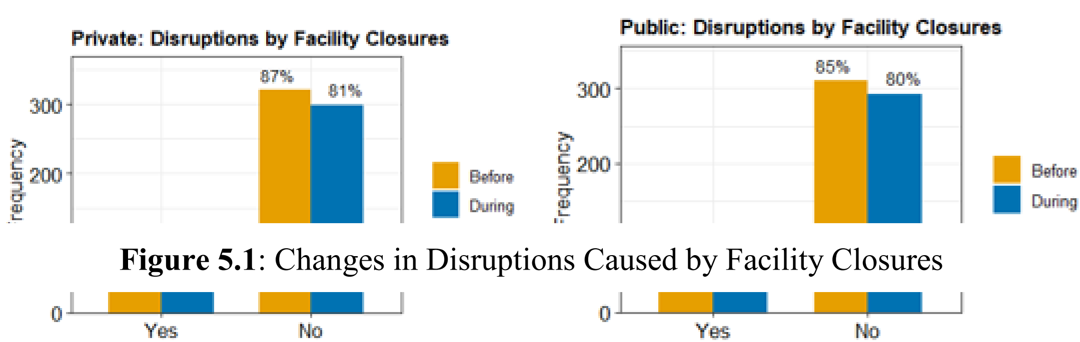


Figure 5.1: Changes in Disruptions Caused by Facility Closures

about real-time truck parking availability surprisingly did not effectively reduce problems with adhering to HOS regulations as a result of a lack of parking. Before the pandemic, the parameter of this variable was normally distributed, with a mean of - 0.243 and a standard deviation of 0.106, which means that only 1.1 percent of drivers who communicated with other drivers avoided HOS adherence issues before the pandemic. Not using real-time truck parking availability tools was also significant, but this parameter estimated that only 0.4 percent of drivers avoided HOS adherence issues. This was consistent with the finding during the pandemic. Not using real-time truck parking availability tools tended to decrease the frequency of a lack of parking causing HOS adherence issues for only 1.3 percent of drivers. After the pandemic, the use of websites was not reliable in helping drivers find adequate parking; this parameter estimated an increase in HOS adherence issues.

Fatigued driving had a positive influence over the frequency of a lack of parking causing HOS adherence problems. Before the pandemic, rarely or never driving tired decreased the frequency of struggling to find adequate parking for nearly all respondents. However, during the pandemic, driving very often while tired increased the occurrence of problems in adhering to HOS regulations.

5.2.6. Truck Configuration

The final factor found to be significant before the pandemic was related to truck configuration characteristics. Single-unit trucks were estimated to have a higher probability of facing HOS adherence problems as a result of a lack of parking. Of the surveyed drivers, 39 percent were single-unit drivers, but nationally they made up 77.6 percent of the total number of registered trucks (Bureau of Transportation Statistics, 2019). The higher occurrence of problems faced by single-unit trucks could be related to the findings presented in the most recent ATA truck parking survey, which revealed that there were more than 11 truck drivers for every one parking space in the nation, and 98 percent of truck drivers had problems finding safe truck parking (McNally, 2021). Coupled with the finding from this survey that one in four drivers admitted that they were willing to park illegally, these findings provide a better understanding of the impacts brought on by the shortage of truck parking.

CHAPTER 6. CONCLUSIONS

The study focused on the factors that affect truck drivers' ability to adhere to HOS regulations during events such as pandemics and similar system disruptions. As discussed in detail, there is an inherent correlation between HOS adherence and a lack of available parking. This correlation was confirmed by a highly significant tetrachoric correlation and error term correlation coefficient (ρ). This statistical finding complimented existing research that has determined that the search for adequate truck parking has created additional problems for truck drivers (McCartt et al., 2008; McNally, 2021). To legally keep working, drivers must maximize their productive time down to the minute to meet specific HOS requirements, in addition to any productivity expectations. Currently, because of a shortage of parking, the average driver spends 56 minutes of available drive time every day looking for an adequate spot. Because of this correlation, a random parameter bivariate ordered probit model was fitted with the frequency of HOS adherence problems caused by a lack of parking as the dependent variable.

A total of 35 statistically significant variables, 22 of which were random and normally distributed, were included in the final models following a stepwise procedure. Twenty-one significant variables were found to specifically influence a driver's ability to find adequate parking before the pandemic, and 15 significant variables were found to have an effect during the pandemic. Overall, eight variables (locating parking on Monday, sometimes or never participating in team driving, experiencing a disruption of services or closures of public facilities, disruption of vending machine access at all facilities, and no use of real-time parking availability tools) were found to affect the likelihood of a truck driver experiencing HOS issues before and during the pandemic.

Of those eight variables, sometimes or never participating in team driving, parking on a Monday, or experiencing disruptions of vending machine access at public facilities increased the likelihood of a driver experiencing HOS adherence problems during the pandemic. Team drivers are inherently more effective at locating adequate parking because of the additional help in searching. Similarly, looking for parking on a Monday increased the probability of a driver violating HOS limitations likely because of the increased levels of traffic and truck activity during weekdays. This finding was consistent with those of Boris et al. (2016), who found that searching for parking is more difficult on weekdays.

Interestingly, use of websites as real-time parking availability tools, frequently driving tired, normally starting driving at mid-day, and experiencing disruptions of takeout/drive-through services at public facilities or disruptions of truck wash stations and other services at private facilities also increased the likelihood of a lack of parking causing HOS adherence issues during the pandemic. These findings were consistent with the significant changes brought on by the pandemic. Before the pandemic, rarely or never driving tired decreased the frequency of struggling to find adequate parking for nearly all respondents. However, during the pandemic, driving frequently while tired increased the occurrence of problems in adhering to HOS regulations. Similarly, drivers' normal driving start times were significantly affected by the pandemic; 50 percent more drivers started driving at mid-day, and 140 percent more started in the afternoon during the pandemic. The significant changes in driving start time were likely correlated with decreases in passenger vehicle traffic and congestion levels, a finding supported by the findings from the ATRI and OOIDA survey (The American Transportation Research Institute and The OOIDA Foundation, 2020). Lastly, these findings ascertained that the largest impact on trucking operations as a result of the pandemic and regulatory changes was on disruptions of services at public and private facilities. The lack of available resources and services presented the greatest challenge for drivers as they supported emergency relief efforts across the country.

Factors affected by the COVID-19 pandemic and changes in HOS regulations were determined in this study. The methods used in this analyses can be used as a framework for future studies that intend to further investigate changes in regulatory rules, such as the newest final HOS rule implemented in June 2020. Agencies and CMV carriers can use the results of this study to justify the need for certain policies or strategies that may potentially increase HOS adherence and in return improve roadway safety. For instance, parameters related to facility service disruptions, truck parking issues, and fatigued driving have an effect on driver behavior, and this information can be used to create resilient supply chains and infrastructure.

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