EFFECTS OF TRUCKING REGULATORY RELAXATIONS ON FREIGHT SAFETY IN OREGON

Final Report

SPR 863

RESEARCH

Oregon Department of Transportation

EFFECTS OF TRUCKING REGULATORY RELAXATIONS ON FREIGHT SAFETY IN OREGON

Draft Final Report

SPR 863

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16. Abstract

This study explores the effects of pandemic-related trucking relaxations on freight safety in Oregon. A historical review of trucking relaxations before and during the pandemic is conducted and compared. Using traffic volume levels and key pandemic dates, three time periods were chosen for analysis: (1) pre-pandemic, (2) a low VMT pandemic period with trucking relaxations in effect, and (3) a normal VMT pandemic period with trucking relaxations in effect. These periods were considered for a descriptive analysis in which a series of proportions tests were conducted to identify overrepresentations. Following the descriptive analysis, a series of freight safety behavior models were developed to describe three key safety performance measures: crash frequency, crash rate, and injury severity. In addition to disaggregate data models and transferability tests, pooled models were developed to determine the effects of the time periods on these safety measures. Results from the analysis are compared across time periods (relative to the pre-pandemic period) to determine if there were significant changes in the periods coinciding with trucking relaxations. This study concludes by providing a comprehensive conclusion and recommendations.

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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	millimeters squared	mm^2
ft^2	square feet	0.093	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometers squared	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	ml
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	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	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit	(F-32)/1.8	Celsius	°C

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	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
m^2	meters squared	1.196	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	kilometers squared	0.386	square miles	mi^2
		VOLUME		
ml	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celsius	1.8C+32	Fahrenheit	°F

*SI is the symbol for the International System of Measurement

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DISCLAIMER

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1.0 INTRODUCTION

Due to COVID-19 and the increased demand of essential goods, the Federal Motor Carrier Safety Administration (FMCSA) announced Emergency Declaration No. 2020-002. This support for direct emergency assistance for specific supply chains granted emergency relief from 49 CFR § 395.3: maximum driving time for motor carriers or its drivers to restore essential services or supplies that remain in short supply due to current supply chain issues. The Oregon Commerce and Compliance Division adheres to and enforces Oregon laws, as well as U.S. DOT regulations in Title 49, which includes the Emergency Declaration No. 2020-20 component. In June 2020, FMCSA also announced four revised provisions regarding hours-of-service that expanded short-haul exceptions, adverse driving conditions, break requirements, and a sleeper berth provision.

The Emergency Declaration and revised provisions created the first substantial change related to hours-of-service in nearly two decades. Additionally, Oregon SB 1601 stated that Oregon Department of Transportation enforcement staff would not be issuing citations for operating a vehicle without driving privileges and failing to register a vehicle through December 31, 2020. Oregon, pursuant to the extension of the Emergency Declaration, also waived Medical Examiner's Certificates for specific drivers and periods through November 30, 2021.

With decreased passenger vehicle traffic and temporary relief of freight bottlenecks, national surveys indicated that trucks were consistently traveling at higher speeds and increases in drivers stating that they were driving fatigued. Although there has been some work on general patterns and driver behavior during this time, little attention has been paid to the impacts of these changes on safety in a quantitative manner.

1.1 OBJECTIVES

This work conducts a comprehensive crash data analysis to determine the effects of trucking regulatory relaxations on freight-related safety in Oregon. Through the analysis, this work provides a framework to evaluate the impacts of policy and regulatory changes on truck crash trends in Oregon. This work identifies key truck crash trends considering frequency, rate, and severity, and develops disaggregate crash behavior models to identify significant factors, including the regulatory changes/time periods, on truck crash behavior.

1.2 ORGANIZATION OF REPORT

This report first presents the findings from a comprehensive review of all relevant policy changes in the trucking industry for both before and during the pandemic.

Following the DOT scan of trucking relaxations, a data analysis is conducted. First, a series of descriptive statistics are presented by key time periods considered (pre-COVID, during COVID with low exposure, and during COVID with "back-to-normal" exposure). The descriptive statistics include key safety trends within Oregon and a series of z-tests of proportions to determine if proportions between time periods are significantly different.

After the descriptive analysis, a series of safety behavior models are developed to describe injury severity, crash frequency, and crash rate with significant contributing factors. The approach taken consists of a disaggregate data approach in which each time period considered is analyzed separately and compared. Using the results of the crash behavior models, an assessment of how contributing factors changed relative to the pre-COVID period is presented.

This report closes with conclusions and recommendations.

2.0 REGULATORY RELAXATIONS IN THE TRUCKING INDUSTRY

States and the Federal Motor Carrier Safety Administration (FMCSA) have a history of issuing various exemptions and relaxations for motor carriers by declaring a State of Emergency long before the COVID-19 pandemic. The DOT scan for this work consisted of determining elements of trucking regulations that states and the federal government had exempted for motor carriers in the years preceding the COVID-19 pandemic and what exemptions were provided during pandemic.

This information is tabulated through FMCSA backlogs, state websites, news records, and notifications provided by motor carrier associations. During the review, it was found that some information was inaccessible for certain states and years. Therefore, the background provided in this work may not be exhaustive.

Throughout the review, it was determined that “proclamations” or “declarations of emergency” were the most common verbiage used by state agencies to declare a state of emergency. Herein, these terms are used interchangeably to refer to states of emergency depending on the verbiage used by the document reviewed. Any state of emergency that did not include transportation-related exemptions was not included in the review.

Although many exemptions target rest and driver break requirements as given in Title 49 CFR § 395 Hours of Service of Drivers, Part 395 is just one subpart of Subchapter B Parts 390-399 of the FMCSA Regulations, all of which can be regulations that can be relaxed under a State of Emergency. Parts 390-399 establish national guidelines for the safe operation of motor carriers, including aspects such as driver qualifications, general guidelines, vehicle fitment, carrier inspections, hazardous materials, and others. Further, CFR § 390.23 provides guidelines of Relief from Regulations based on national, regional, or local emergencies. Specifically, CFR § 390.23 allows for regions or states to be exempt from one or all portions of Parts 390-399 during declared emergencies. Table 2.1 provides a summary of Title 49 Subchapter B parts.

Table 2.1: Summary of Title 49 Subchapter B Parts

Part	Topic
350	Motor Carrier Safety Assistance Program (MCSAP) and High Priority Program
355	[Reserved]
356	Motor Carrier Routing Regulations
360	Fees for Motor Carrier Registration and Insurance
365	Rules Governing Applications for Operating Authority
366	Designation of Process Agent
367	Standards for Registration with States
368	Application for a Certificate of Registration to Operate in Municipalities in the United States on the United States-Mexico International Border or Within the Commercial Zones of Such Municipalities.
369	Reports of Motor Carriers
370	Principles and Practices for the Investigation and Voluntary Disposition of Loss and Damage Claims and Processing Salvage
371	Brokers of Property
372	Exemptions, Commercial Zones, and Terminal Areas
373	Receipts and Bills
374	Passenger Carrier Regulations
375	Transportation of Household Goods in Interstate Commerce; Consumer Protection Regulations
376	Lease and Interchange of Vehicles
377	Payment of Transportation Charges
378	Procedures Governing the Processing, Investigation, and Disposition of Overcharge, Duplicate Payment, or Overcollection Claims
379	Preservation of Records
380	Special Training Requirements
381	Waivers, Exemptions, and Pilot Programs
382	Controlled Substances and Alcohol Use and Testing
383	Commercial Driver's License Standards; Requirements and Penalties
384	State Compliance with Commercial Driver's License Program
385	Safety Fitness Procedures
386	Rules of Practice for FMCSA Proceedings
387	Minimum Levels of Financial Responsibility for Motor Carriers
388	[Reserved]
389	Rulemaking Procedures—Federal Motor Carrier Safety Regulations
390	Federal Motor Carrier Safety Regulations, General
391	Qualifications of Drivers and Longer Combination Vehicle (LCV) Driver Instructors
392	Driving of Commercial Motor Vehicles
393	Parts and Accessories Necessary for Safe Operation
394	[Reserved]
395	Hours of Service of Drivers
396	Inspection, Repair, and Maintenance
397	Transportation of Hazardous Materials; Driving and Parking Rules
398	Transportation of Migrant Workers
399	Employee Safety and Health Standards

2.1 FEDERAL BACKGROUND

FMCSA declarations are issued from one of four service centers (Eastern, Southern, Midwestern, and Western) that monitor and communicate with states geographically closest to their location. State exemptions for any Parts 390-399 may be granted for up to a 30-day period through Title 49 CFR § 390.23, though they can only be declared by FMCSA, a State of Emergency declared by the governor of a state (or their authorized representative), or a sitting President.

While states can declare temporary suspensions from specific portions of Parts 390-399, such as Part 395 Hours of Service of Drivers, FMCSA in the majority of their declarations relieve all of Parts 390-399. This allows states to balance relief needs against potential adverse effects of removing enforcement for any one element of the regulations. However, because FMSCA must grant permission and recognize states' own temporary relaxations due to declared emergencies, there are many instances where declarations from individual states overlap with those given by FMCSA regional or national declarations that are already in place.

2.2 STATE BACKGROUND

Although a majority of states follow a similar gubernatorial executive order process establishing duress and providing outlined transportation regulatory changes, a minority of states' governors only establish cause and leave internal branches of state government, such as Departments of Transportation, state revenue offices, and/or law enforcement agencies to issue specific exemption guidance. State declarations of emergency and subsequent relaxations of portions of Title 49 often coincide with natural disasters (e.g., hurricanes, severe storms, flooding, tornadoes), where the urgency to deliver relief aid and supplies quickly can outweigh potential safety considerations. Some states, however, declare States of Emergency for other reasons, such as energy sector issues or agricultural needs; this is often seen if either are a main economic output of the state.

2.3 REGULATORY RELAXATIONS BEFORE THE COVID-19 PANDEMIC

To understand the impacts of regulatory relaxations outside of the COVID-19 pandemic, actions taken by states were reviewed for over a period of seven years leading up to the changes given in response to COVID; this included all actions from 2013 through 2019.

2.3.1 Federal-Level

The number of declarations during the seven-year period before the pandemic was 86 (all issued by FMCSA). Table 2.2 provides a summary of the reasons for FMCSA issued declarations by year reviewed.

Table 2.2: Pre-Pandemic Summary of FMSCA Declarations

	Emergency Declarations		For Natural Disaster and/or Relief Aid		For Petroleum and/or Agriculture	
Year	**Number**	**% of Total**	**Number**	**% of Year**	**Number**	**% of Year**
2013	1	1%	1	100%	0	0%
2014	20	23%	4	20%	16	80%
2015	0	0%	0	-	0	-
2016	5	6%	1	20%	4	80%
2017	19	22%	14	74%	5	26%
2018	21	24%	9	43%	12	57%
2019	20	23%	9	45%	11	55%
Average Per Year	**12**	-	5	-	7	-
Total	**86**	-	38	-	48	-
As Percent of Total	**100%**	-	44%	-	56%	-
2013	1 [lowest]					
2018	18 [highest]					

2.3.2 State-Level

Among all state emergency declarations in the pre-pandemic period, the two primary reasons for motor carrier regulatory relaxations were related to petroleum products (e.g., propane for heating and agricultural) and relief aid (e.g., response to severe weather or natural disasters). Of 282 State of Emergency declarations during this time period, 57% were for petroleum distribution, 35% for disaster aid, and 8% for other aspects (e.g., agriculture needs). A total of eight states (16%) did not appear to declare transportation-related States of Emergency during this seven-year period.

Petroleum, mostly propane, is overrepresented in part due to a large number of declared emergencies as a result of harsh winter weather conditions, thus necessitating the need for heating energy. In addition, agriculture relies on petroleum products to speed up harvests. Natural disasters also result in a high need for energy.

Figure 2.1 shows the number of declarations that relaxed trucking regulations in the pre-pandemic period. Minnesota stands out as the state with the highest number of declarations at 18, followed closely by North Carolina with 17. By contrast, the per-state average number of declarations was 5.6 and the median was 5.5. Declarations made by Oregon during this time period were four, less than the average and lower than the median.

Figure 2.2 shows the total number of declarations relaxing trucking regulations at the federal and state levels, the per-state average, and the total number of declarations in Oregon. Figure 2.3 provides the number of declarations that relaxed specific regulations; namely, hours-of-service, over-dimension and/or overweight restrictions, permitted and/or licensing, and relaxations to the International Fuel Tax Agreement (IFTA) and/or the International Registration Plan (IRP).

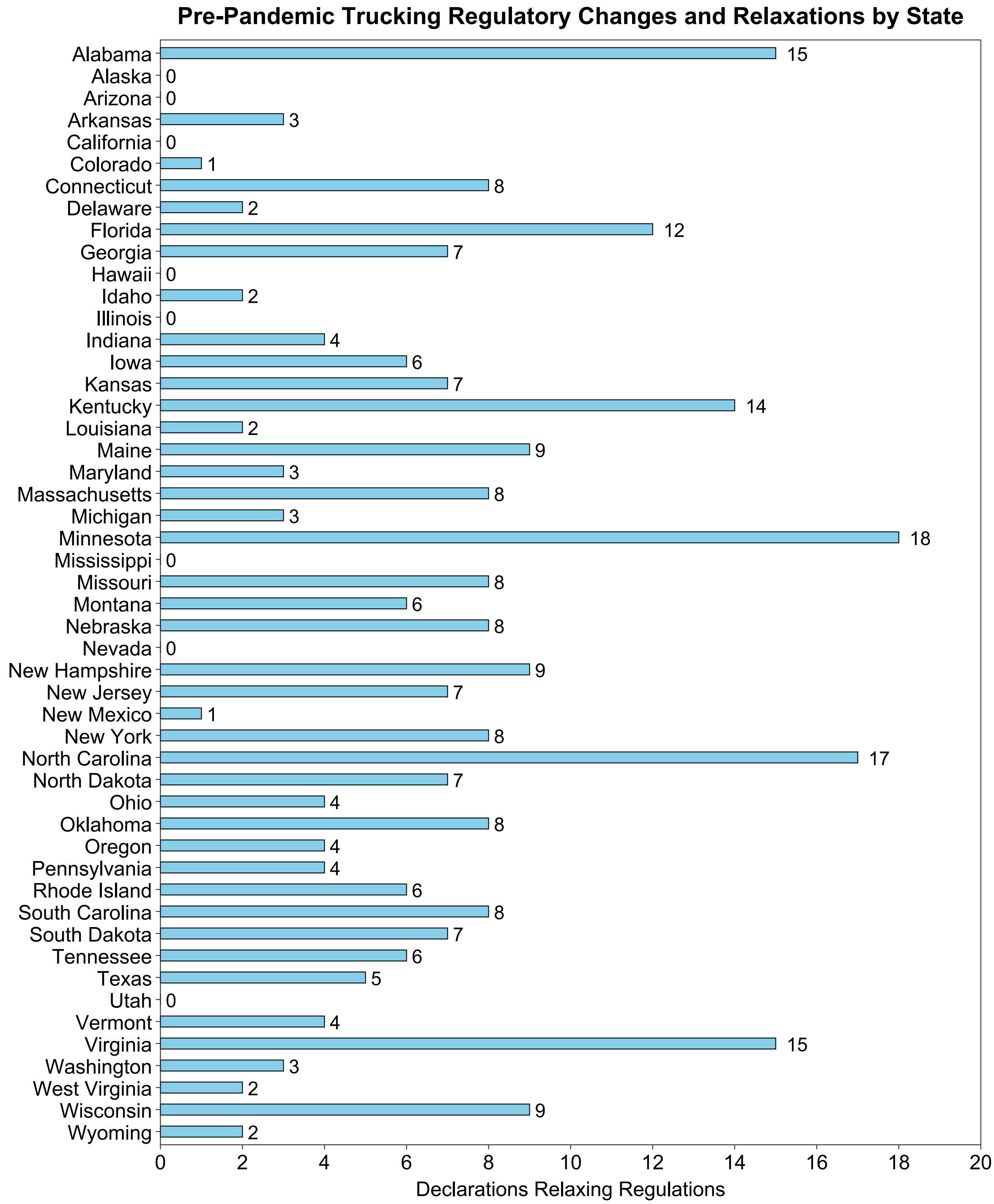

Figure 2.1: Pre-Pandemic Declarations on Trucking Regulatory Relaxations by State

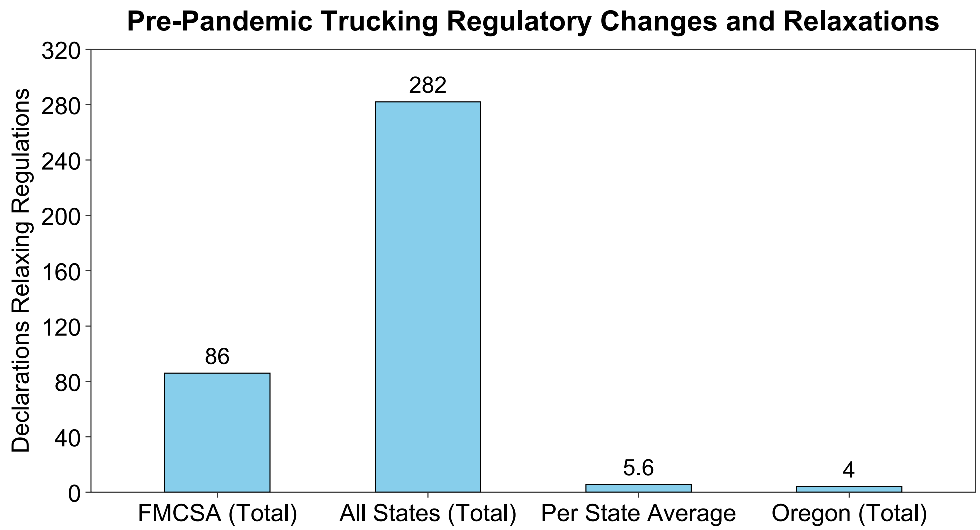

Figure 2.2: Pre-Pandemic Trucking Regulatory Relaxations at the Federal Level, State Level, and in Oregon

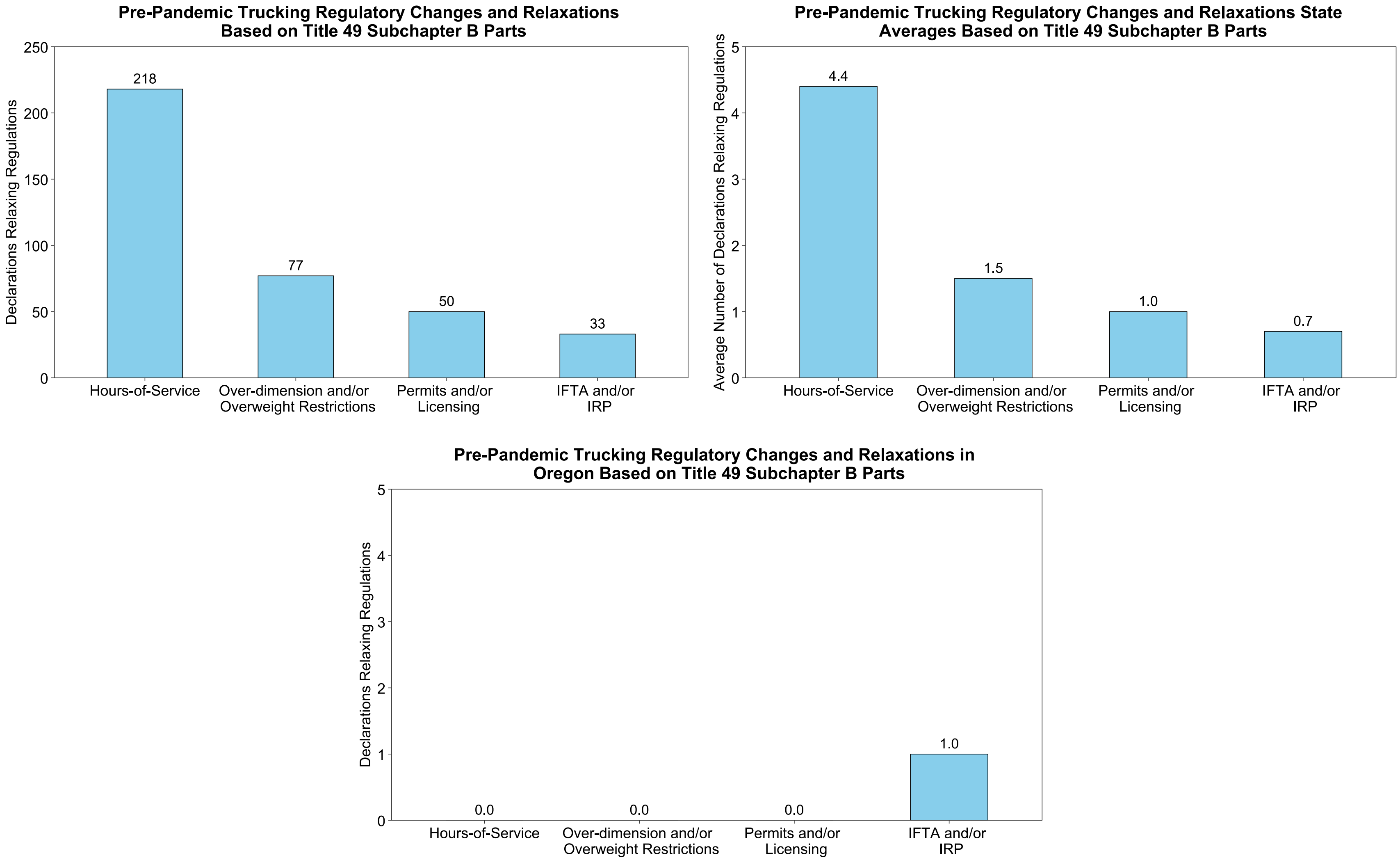

Figure 2.3: Pre-Pandemic Trucking Regulatory Relaxations by Hours-of-Service, Over-dimension and/or Overweight Restrictions, Permits and/or Licensing, and IFTA and/or IRP

Table 2.3 provides a summary of state declarations during this seven-year period. Regulatory relaxation of Part 395 Hours of Service of Drivers was the most declared relaxation during this period. Of the 282 State of Emergency declarations, 77% (218) were temporary exemptions from hours-of-service, compared to 16% (46) that relieved all of Parts 390-399. Just over 50% of states (27) also issued supplemental state-level relief within their own borders, such as exemptions for overweight restrictions, over-dimension restrictions, the International Fuel Tax Agreement, and the International Registration Plan.

Table 2.3: Pre-Pandemic State Declarations Summary

	Emergency Declarations	**Hours-of-Service**		**Over-dimension and/or Overweight Restrictions**		**Permitting and/or Licensing**		**IFTA and/or IRP**	
Agency	**Total**	**Number**	**% of Total**	**Number**	**% of Total**	**Number**	**% of Total**	**Number**	**% of Total**
FMCSA	86	-	-	-	-	-	-	-	-
All States	282	218	77%	77	27%	50	18%	33	12%
Per State Average	5.6	4.4	77.3%	1.5	27.3%	1.0	17.7%	0.7	11.7%
Oregon	4	0	0%	0	0%	0	0%	1	25%
Other States									
Alaska Arizona California Hawaii Illinois Mississippi Nevada Utah	0								
Colorado New Mexico	1 [lowest]								
Minnesota	18 [highest]								

2.3.3 Oregon

Four transportation-specific exemptions were issued in Oregon in the pre-pandemic period. Gubernatorial declarations in Oregon may or may not incorporate FMCSA relaxations within the executive order and may be supplemented by guideline bulletins from the Commerce and Compliance Division (CCD) of the Oregon Department of Transportation.

As is common in the region, each of the four declared States of Emergency in Oregon were in response to wildfires. In each declaration, relaxations from part or all of Parts 390-399 were granted for motor carriers and drivers providing emergency materials and services as part of emergency relief efforts in affected areas.

On July 25, 2013, there was a gubernatorial declaration in response to a fire disaster, where CCD issued relief from all Parts 390-399 through August 25, 2013. The following year, CCD again issued relief for another wildfire (this lasted July 17, 2014 to August 16, 2014). A declaration was also issued in August 2015 that covered hours-of-service for motor carriers transporting aviation fuel used to fight wildfires. The final declaration was in August 2017, which was again related to wildfires. Based on the review, there appears to be no further declarations until those issued as part of the pandemic response.

2.4 REGULATORY RELAXATIONS DURING THE COVID-19 PANDEMIC

The four FMCSA service centers began issuing national regulatory relaxations of Title 49 Subchapter B Parts 390-399 to ease carriers' burden for delivering relief materials at the onset of the pandemic. The year would also see other events that have led to regulatory relaxations (e.g., extreme weather, wildfires). Many states issued fewer exemptions during the pandemic, but this was also a shorter duration compared to the pre-pandemic review, as well as there being single declarations that were extended multiple times.

2.4.1 Federal-Level

The number of federal declarations during the pandemic, all issued by FMCSA, was 78. A summary of these declarations is given in Table 2.4.

Table 2.4: Pandemic Summary of FMSCA Declarations

Year	Emergency Declarations		For COVID-19		For Natural Disaster and/or Relief Aid		For Petroleum and/or Agriculture		Other	
	Number	% of Total	Number	% of Year	Number	% of Year	Number	% of Year	Number	% of Year
2020	25	32%	8	32%	13	52%	4	16%	0	0%
2021	25	32%	6	24%	8	32%	9	36%	2	8%
2022	28	36%	5	18%	12	43%	9	32%	2	7%
Average Per Year	**26**	**-**	**6**	**-**	**6**	**-**	**11**	**-**	**7**	**-**
Total	**78**		**19**		**33**		**22**		**4**	
As Percent of Total	**100%**		**24%**		**42%**		**28%**		**5%**	
2020, 2021	25 [lowest]									
2022	28 [highest]									

2.4.2 State-Level

A majority of states (43) declared transportation-related States of Emergency due to the pandemic, most of which were in conjunction with the FMCSA declarations. Many of the state declarations, however, were only acknowledgements of transportation impacts and did not specifically relax regulations above and beyond what was relaxed by FMCSA. A total of 24 states specified regulatory relaxations that were in-line with FMCSA. With the exception of Arkansas, exemptions for overweight, over-dimension, the International Fuel Tax Agreement, the International Registration Plan, and others were added as supplemental state-level relief.

Seven of 50 states (14%) did not appear to declare any transportation-related States of Emergency of any kind during the pandemic.

Figure 2.4 shows the number of declarations, related to the pandemic, by state. These counts are for those relaxations that went beyond the FMCSA relaxations. Minnesota stands out as the state with the highest number of declarations with 11, followed by South Carolina with five and New York with four. By contrast, the per-state average number of declarations was 0.98. Oregon has just one during this time period but was extended multiple times.

Figure 2.5 shows the number of declarations relaxing trucking regulations at the federal and state levels, the per state average, and the number of declarations in Oregon. Figure 2.6 shows the number of declarations that relaxed specific regulations; namely, hours-of-service, over-dimension and/or overweight restrictions, permitting and/or licensing, and relaxations to the International Fuel Tax Agreement and/or the International Registration Plan.

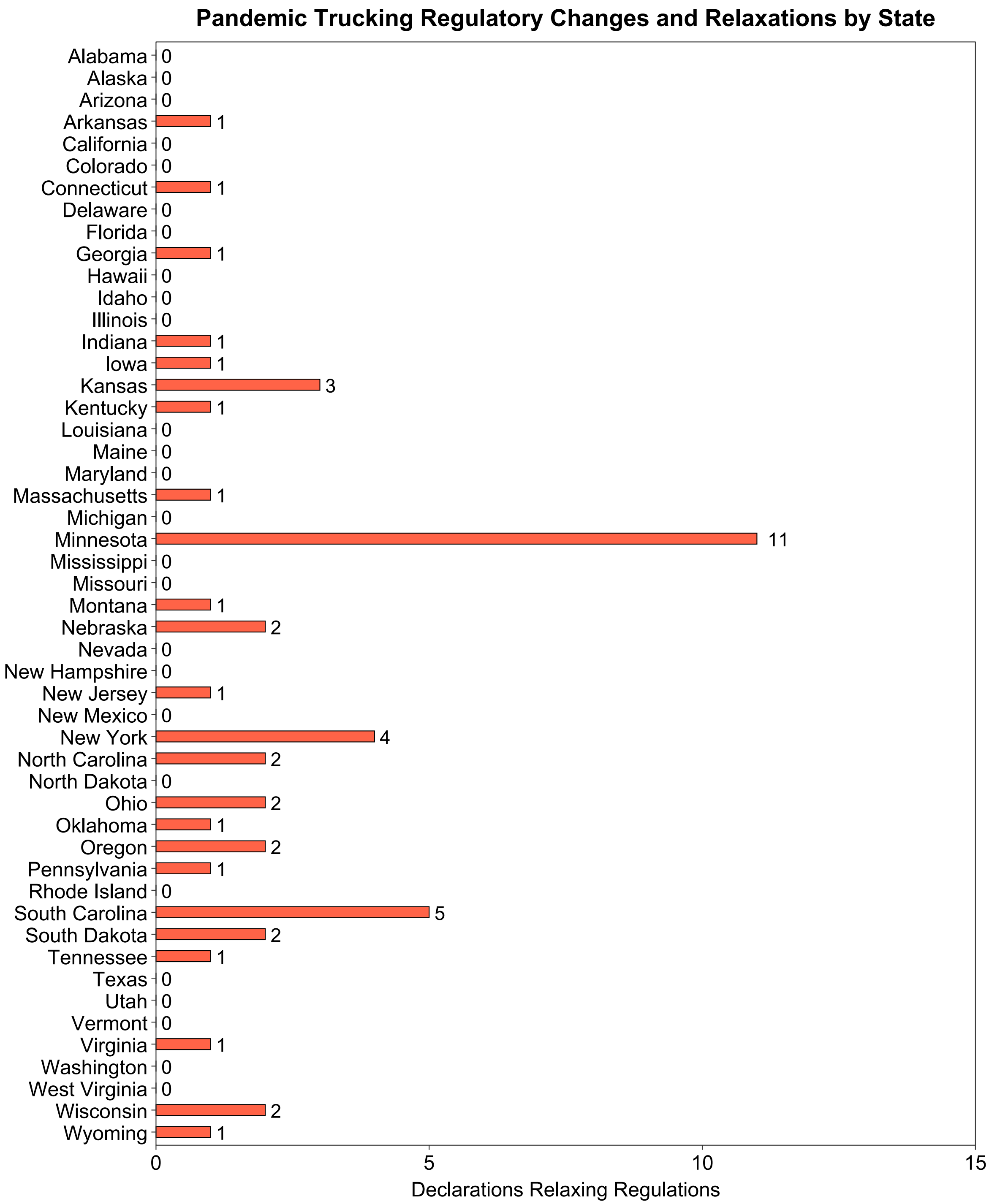

Figure 2.4: Pandemic Declarations on Trucking Regulatory Relaxations by State

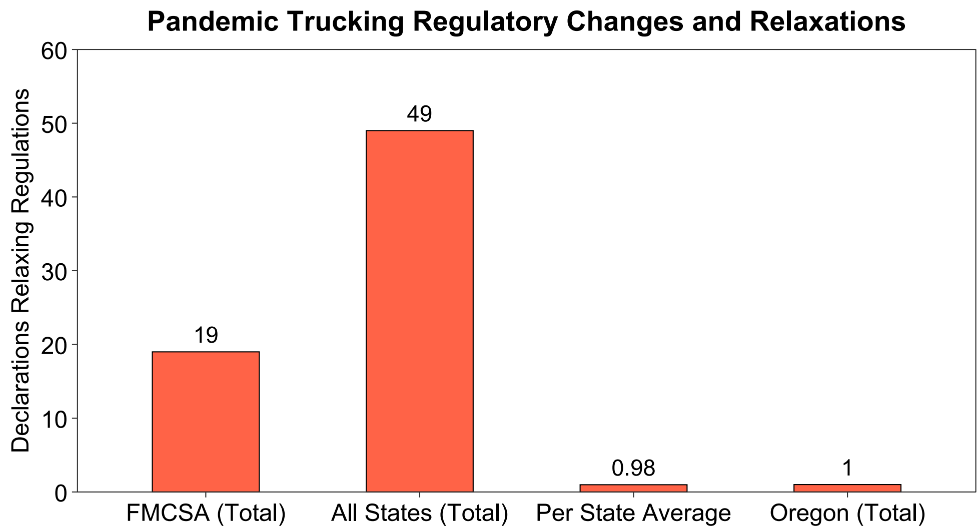

Figure 2.5: Pandemic Trucking Regulatory Relaxations at the Federal Level, State Level, and in Oregon

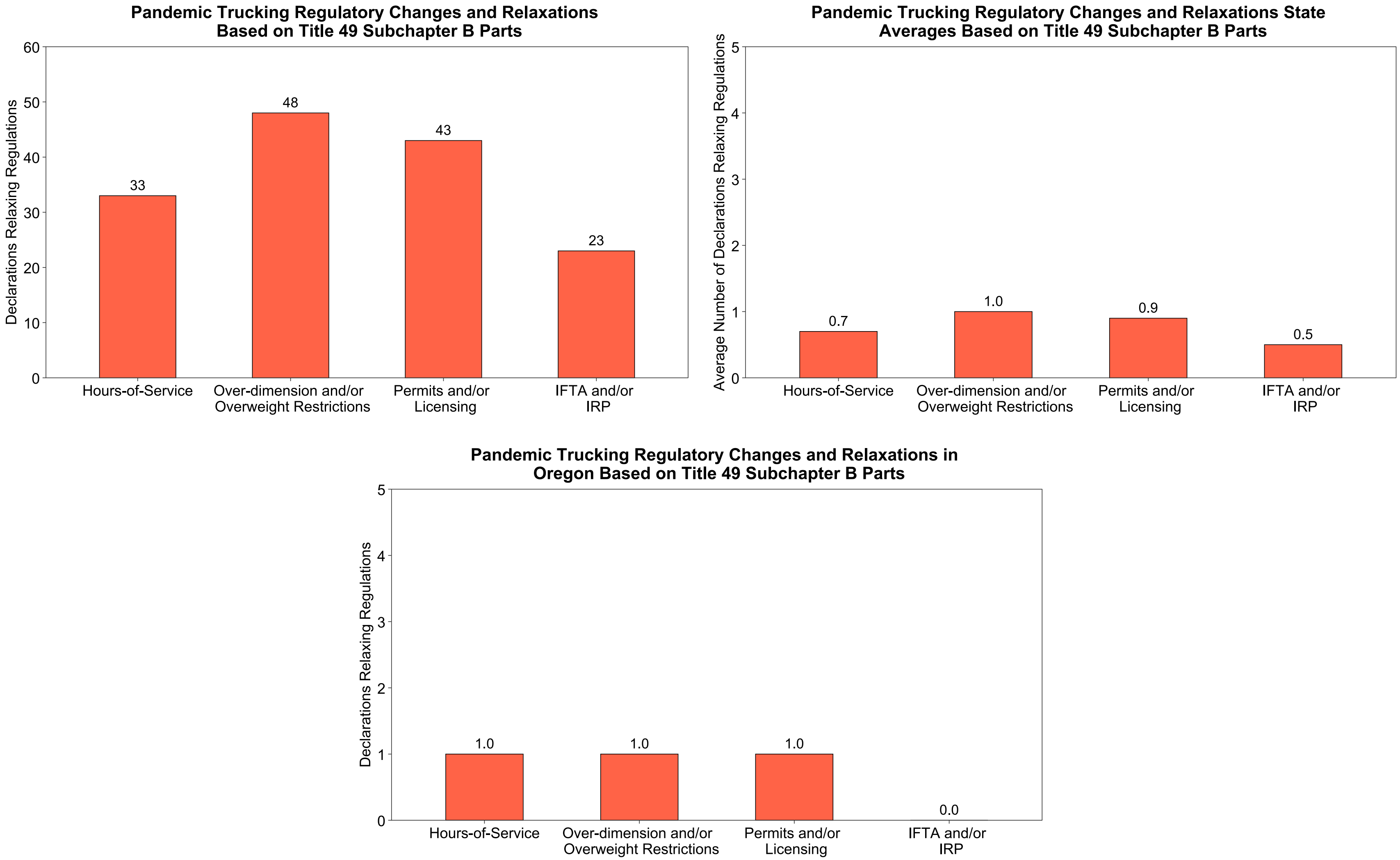

Figure 2.6: Pandemic Trucking Regulatory Relaxations by Hours-of-Service, Over-dimension and/or Overweight Restrictions, Permits and/or Licensing, and IFTA and/or IRP

There were 49 pandemic-related State of Emergency declarations during the three-year period considered, as shown in Table 2.5. Of the 49, suspensions for over-dimension and/or overweight trucks were utilized the most (declared in 48 of the 49, with Arkansas as the one state that did not declare such relaxations). Further, 33 declarations issued temporary exemptions from Part 395 Hours of Service of Drivers and 16 declarations issued temporary exemptions from all Parts 390-399. Lastly, 43 of the declarations issued state-level relief for permitting and/or registration.

Table 2.5: Pandemic State Declarations Summary

Agency	**Emergency Declarations**	**Hours-of-Service**		**Over-dimension and/or Overweight Restrictions**		**Permitting and/or Licensing**		**IFTA and/or IRP**	
	Total	**Number**	**% of Total**	**Number**	**% of Total**	**Number**	**% of Total**	**Number**	**% of Total**
FMCSA	19	-	-	-	-	-	-	-	-
All States	49	33	67%	48	98%	43	88%	23	47%
Per State Average	0.98	0.7	67.3%	1.0	98%	0.9	87.8	0.5	46.9%
Oregon	1	1	100%	1	100%	1	100%	0	0%
Other States									
26 States	0								
14 States	1								
6 States	2								
Kansas	3 [next lowest]								
Minnesota	22 [highest]								

2.4.3 Oregon

Six transportation-specific exemptions were issued in Oregon during the pandemic. Gubernatorial declarations in Oregon may or may not incorporate FMCSA relaxations within the executive order though they may be supplemented by guideline bulletins from the Commerce and Compliance Division within the Oregon Department of Transportation.

Oregon Executive Order No. 20-03 declared a State of Emergency due to COVID-19 on March 8, 2020 and was in effect for 60 days. This order allowed Oregon agencies to make changes to regulations as necessary. On March 16, 2020, ODOT suspended enforcement of commercial vehicle size and weight permits, requirements for permitting, registration, tax enrollment, Part 395 Hours of Service of Drivers, and issued temporary passes for single trips or short-time operations. These remained in effect until the state of emergency was terminated.

The Governor extended Executive Order No. 20-03 seven times until it reached its end on June 30, 2022.

2.5 REGULATORY RELAXATIONS SUMMARY

This review aimed to provide a background regarding motor carrier regulation relaxation before the pandemic and during the pandemic. The COVID-19 pandemic led to an increased demand of essential goods, whereby FMSCA issued national declaration No. 2020-002 granting emergency relief from Title 49 CFR Parts 390-399.

Although rest periods and the maximum allowable driving time for motor carriers (Part 395) is a strong focus of states to move needed goods quicker, the consequences from a safety perspective are not fully understood. All Parts 390-399 are intended to establish national regulations for the safe operation and regulation of motor carriers. As observed in the review, there is often a combination of relaxations declared to facilitate the movements of goods and services. Table 2.6 provides a brief review of each topic within Title 49 CFR Parts 390-399.

Table 2.6: Title 49 CFR Parts 390-399 Topics

Part	Topic
390	General Federal Motor Carrier Safety Regulations
391	Qualifications of Drivers and Longer Combination Vehicle (LCV) Driver Instructors
392	Driving of Commercial Motor Vehicles
393	Parts and Accessories Necessary for Safe Operation
394	[Reserved]
395	Hours of Service of Drivers
396	Inspection, Repair, and Maintenance
397	Transportation of Hazardous Materials; Driving and Parking Rules
398	Transportation of Migrant Workers
399	Employee Safety and Health Standards

Despite steep circumstances that separate general regulatory changes before the pandemic and during the pandemic, the type of declarations and their purpose appear more similar than different. The declaration rate per year and per state is slightly higher before the pandemic (5.64 to 4.78), where four additional years were reviewed. This suggests that the pandemic facilitated additional declarations within a shorter time period.

The total of all state transportation declarations per year are greater during the pandemic (about 80 per year compared to 40). Part of this may be attributed to supplemental state-level exemptions outside of those given by FMCSA, such as overweight and over-dimension restrictions. Before the pandemic, supplemental state relaxations were issued approximately 37% of the time during emergency declarations, while these rose to approximately 69% during the pandemic. This is a substantial increase in relaxations outside of Part 395 Hours of Service for Drivers and other Parts 390-399.

Figure 2.7 and Table 2.7 show a comparison of the total number of declarations relaxing trucking regulations at the federal and state levels, the per state average, and the number of declarations in Oregon. Figure 2.8 shows a comparison of the number of declarations that relaxed specific regulations; namely, hours-of-service, over-dimension and/or overweight restrictions, permitting and/or licensing, and relaxations to the International Fuel Tax Agreement

(IFTA) and/or the International Registration Plan (IRP). Despite the pre-pandemic period covering a wider period, the trends appear to show the impact of the pandemic on an increased number of regulatory relaxations.

Overall, the most common declared emergencies involve severe weather, particularly during wintertime, that require relief efforts. Another common declaration was related to a state's economy; for example, states that rely on agriculture. Nevertheless, the temporary suspension of hours-of-service was enacted more than any other relief mechanism available.

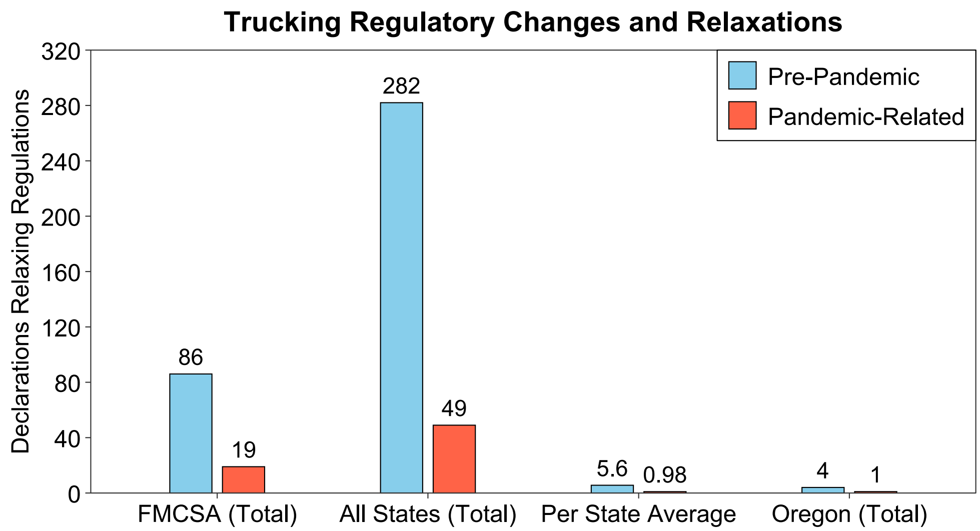

Figure 2.7: Comparison of Pre-Pandemic and Pandemic-Related Trucking Regulatory Relaxations at the Federal Level, State Level, and in Oregon

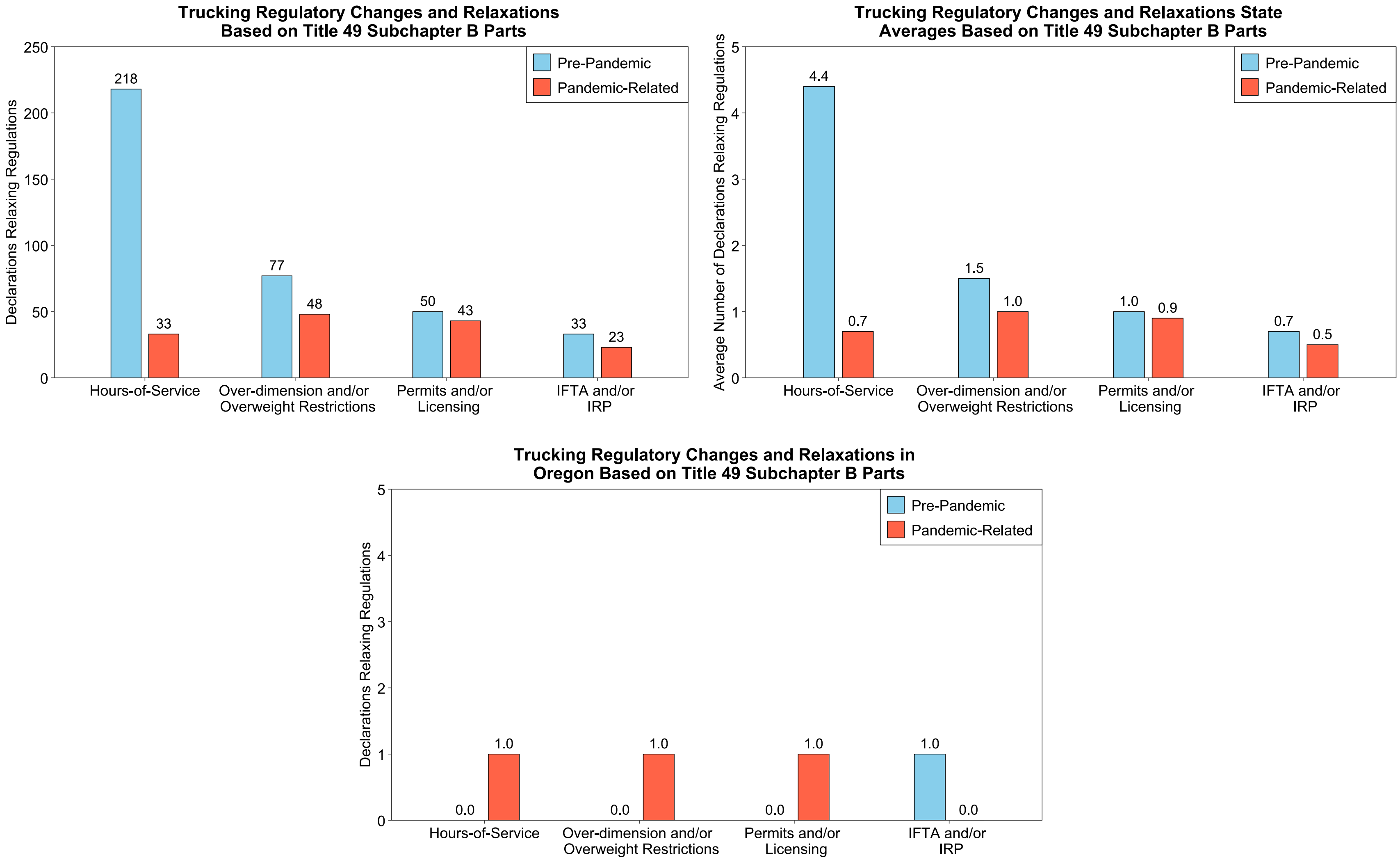

Figure 2.8: Comparison of Pre-Pandemic and Pandemic-Related Trucking Regulatory Relaxations by Hours-of-Service, Over-dimension and/or Overweight Restrictions, Permits and/or Licensing, and the International Fuel Tax Agreement and/or the International Registration Plan

Table 2.7: Federal and State Declarations Summary Before and During the Pandemic

Relaxation Period	Agency	Emergency Declarations	Hours-of-Service		Over-dimension and/or Overweight Restrictions		Permitting and/or Licensing		IFTA and/or IRP	
		Total	Number	% of Total	Number	% of Total	Number	% of Total	Number	% of Total
All	FMCSA	86								
All	FMCSA	59								
COVID-19 Only	FMCSA	19								
All	All States	282	218	77%	77	27%	50	18%	33	12%
All	All States	239								
COVID-19 Only	All States	49	33	67%	48	98%	43	88%	23	47%
All	Per State Average	5.6	4.4	77.3%	1.5	27.3%	1.0	17.7%	0.7	11.7%
All	Per State Average	4.8								
COVID-19 Only	Per State Average	0.98	0.7	67.3%	1.0	98%	0.9	87.8	0.5	46.9%
All	Oregon	4	0	0%	0	0%	0	0%	1	25%
All	Oregon	4								
COVID-19 Only	Oregon	1	1	100%	1	100%	1	100%	0	0%

Key for Table 2.7

(blue)	Indicates the pre-pandemic period (2013 through 2019)
(red)	Indicates during the pandemic (2020 through 2022)

3.0 METHODOLOGY

To analyze the effects of trucking regulatory relaxations on freight safety in Oregon, a series of analyses were conducted. First, distinct periods were identified for the disaggregate data analysis. Second, a descriptive analysis was conducted, which included an assessment of the proportions of crash characteristics between time periods.[1] Third, a series of z-tests of proportions were conducted to determine if crash proportions were significantly different among the identified time periods. Next, a series of freight-safety behavior models were developed to describe injury severity behavior, crash frequency behavior, and crash rate behavior among the time periods considered. Lastly, utilizing significant contributing factors identified in the pre-pandemic models, shared contributing factors across time periods were compared, where the pre-pandemic period was considered as the reference scenario.

For all analyses, the ODOT crash data was filtered by vehicle type to represent trucks. The records included in the analysis represent truck-involved crashes and all driver-related information is for that of the truck driver.

The following subchapters provide additional detail for each of the methodologies.

3.1 IDENTIFICATION OF TIME PERIODS

To apply a disaggregate data approach, key time periods needed to be identified. To identify these time periods, traffic volume trends were used. Vehicle miles travelled (VMT) data was obtained from Federal Highway Administration (2023), which resulted in the trends shown in Figure 3.1 to Figure 3.3. Based on these trends, the following three time periods were considered for the disaggregate data analysis:

- Pre-COVID (Apr. 2019 to Mar. 16, 2020)
- COVID Relaxations and Low VMT (Mar. 16, 2020 to Mar. 2021)
- COVID Relaxations and Normal VMT (Mar. 2021 to Dec. 2021)

These periods were chosen based on exposure during each period. The key date to consider is March 16, 2020. On this date, the trucking regulatory relaxations went into effect in Oregon. Figure 3.1 to Figure 3.3 depict the general dip in average monthly VMT from March 2020 to March 2021, with some exceptions in the summer months due to increased outdoor activity as a result of the pandemic. In approximately March 2021, VMT levels had generally reached pre-pandemic levels. In addition, time periods were chosen with sample size consideration (e.g., each period consists of approximately the same number of months). Note that the VMT trends

[1] A series of supplemental descriptive analyses were also conducted and can be viewed in the Appendices.

presented here account for all VMT and not just truck traffic. VMT data to generate these trends was obtained from Federal Highway Administration (2023).

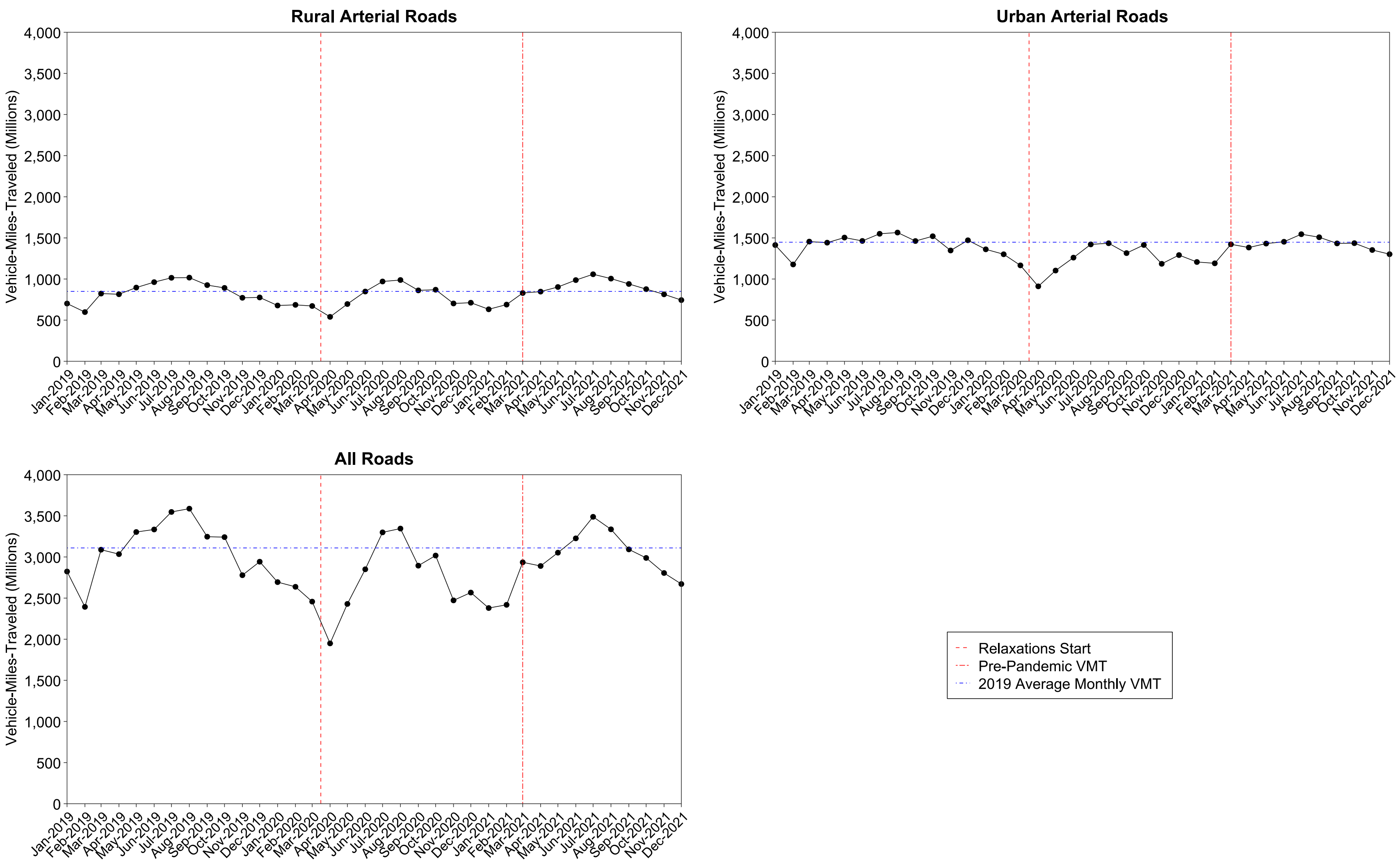

Figure 3.1: Average Monthly VMT in Oregon on Rural Arterial Roads, Urban Arterial Roads, and All Roads from Jan. 2019 to Dec. 2021

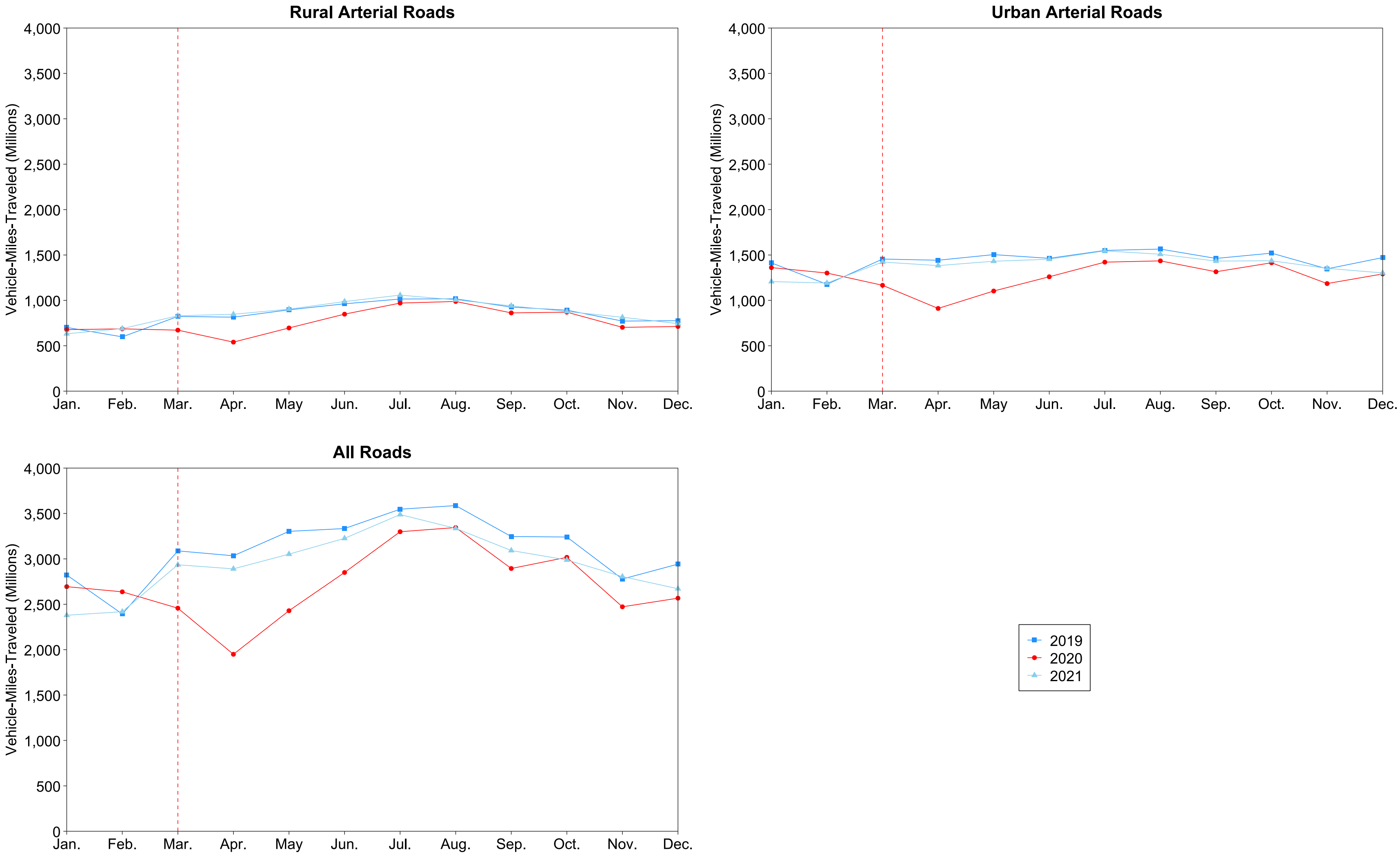

Figure 3.2: Average Monthly VMT in Oregon on Rural Arterial Roads, Urban Arterial Roads, and All Roads by Year

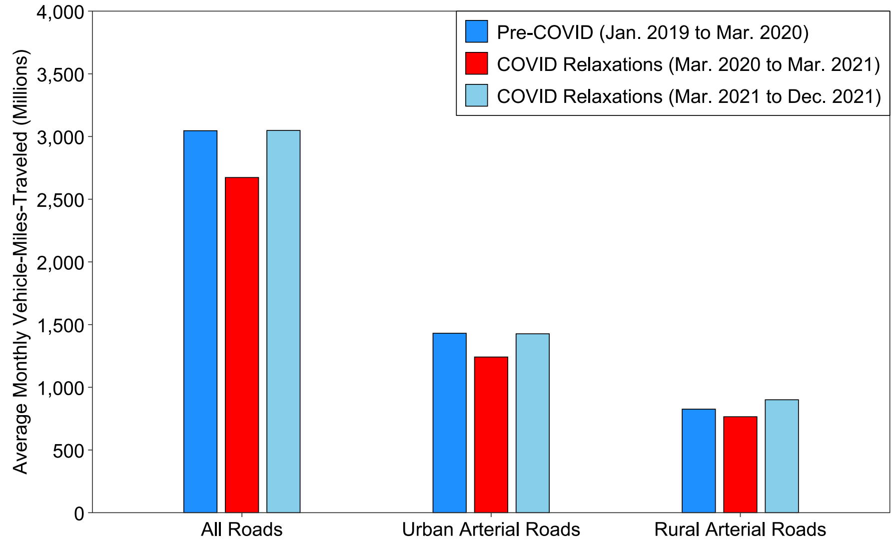

Figure 3.3: Average Monthly VMT in Oregon by Time Period

3.2 DESCRIPTIVE ANALYSIS

For the disaggregate descriptive analysis, two methodologies were considered. First, key crash characteristics as summarized in the Safety Investigation Manual workbook are assessed. The statistics analyzed are crash frequencies and proportions by time period and crash characteristic, and the crash frequencies and proportions by time period, crash characteristics, and severity. Severity is defined as the highest sustained injury in the crash and is considered with the following levels:

- No apparent injury
- Minor injury (suspected minor injury or possible injury)
- Serious injury (suspected serious injury or fatality)

The crash characteristics analyzed, based on key characteristics in the Safety Investigation Manual, include:

- Frequency and proportion of truck-involved crashes by period and severity.
- Frequency and proportion of truck-involved crashes by period, collision type, and severity.
- Frequency and proportion of truck-involved crashes by period, time-of-day, and severity.
- Frequency and proportion of truck-involved crashes by period, day of the week, and severity.

- Frequency and proportion of truck-involved crashes by period, lighting condition, and severity.
- Frequency and proportion of truck-involved crashes by period, road surface condition, and severity.
- Frequency and proportion of truck-involved crashes by period, weather condition, and severity.
- Frequency and proportion of truck-involved crashes by period, truck driver age, and severity.
- Frequency and proportion of truck-involved crashes by period, older truck drivers involved, and severity.[2]
- Frequency and proportion of truck-involved crashes by period, truck driver-level crash cause, and severity.
- Frequency and proportion of truck-involved crashes by period, truck driver residence, and severity.
- Frequency and proportion of truck-involved crashes by period, truck driver gender, and severity.
- Frequency and proportion of truck-involved crashes by period, number of vehicles involved (single- or multi-vehicle crash), and severity.

In addition to visualizing the crash frequencies and proportions, a series of proportions tests were conducted. The proportions tests were z-tests of proportions to determine if there was a statistically significant difference in truck-involved crash proportions between each time period. For example, Pre-COVID (Apr. 2019 to Mar. 16, 2020) was tested against COVID Relaxations (Mar. 16, 2020 to Mar. 2021) and COVID Relaxations (Mar. 2021 to Dec. 2021), while COVID Relaxations (Mar. 16, 2020 to Mar. 2021) was tested against COVID Relaxations (Mar. 2021 to Dec. 2021). This was done for both overall truck-involved crash proportions and the proportions of fatal or suspected serious injury truck-involved crashes.[3]

The z-test of proportions is based on the following null and alternative hypotheses:

$$\boldsymbol{H_o}: \boldsymbol{P_1} = \boldsymbol{P_2} \tag{3.1}$$

[2] Older truck drivers are defined as drivers 65 years or older. This is based on Oregon's Transportation Safety Action Plan.
[3] Proportions tests for within-severity serious injury crashes were also conducted. The results from these tests can be viewed in Appendix A.

$$\boldsymbol{H_A: P_1 \neq P_2} \tag{3.2}$$

where P_1 and P_2 are the proportions of sample one and sample two, respectively (e.g., Pre-COVID (Apr. 2019 to Mar. 16, 2020) and COVID Relaxations (Mar. 16, 2020 to Mar. 2021)).

To determine if the null hypothesis is rejected, a z-statistic is computed, such that:

$$\boldsymbol{Z = \frac{(\hat{P}_1 - \hat{P}_2)}{\sqrt{\hat{P}(1-\hat{P})\left(\frac{1}{N_1} + \frac{1}{N_2}\right)}}} \tag{3.3}$$

with:

$$\boldsymbol{\hat{P}_1 = \frac{S_1}{N_1} \text{ and } \hat{P}_2 = \frac{S_2}{N_2}} \tag{3.4}$$

and:

$$\boldsymbol{\hat{P} = \frac{S_1 + S_2}{N_1 + N_2}} \tag{3.5}$$

where S_1 is the number of crashes for a crash attribute (e.g., rainy weather, daylight condition, etc.), S_2 is the number of crashes for the time period being tested against for the same crash attribute (dry surface, wet surface, snow surface), N_1 is the total number of crashes for the crash attribute category (e.g., road surface condition, lighting condition, driver residence, etc.), and N_2 is the total number of crashes for the crash category of the time period being tested against.

For the proportions test, following previous work (Monsere et al., 2020), a statistical significance threshold of 95% is chosen.

In addition to the crash data descriptive analysis, a descriptive analysis of truck speed and truck counts using weigh-in-motion (WIM) data was conducted. All WIM sites with data were considered and descriptive statistics were determined by truck classification groups following the work of Anderson et al. (2020). These statistics are shown through figures in Appendix B (average hourly speed), Appendix C (speed distributions), and Appendix D (hourly truck counts).

The final descriptive analysis conducted used a third-party data source (Robinsight[4]) to understand drive times and remaining hours-of-service for the time periods considered for the safety analysis. These results are shown in Appendix E.

[4] For additional information on Robinsight, refer to the Robinsight website.

3.3 FREIGHT SAFETY BEHAVIOR MODELS

A series of freight safety behavior models were developed to describe freight safety behavior under different regulatory periods. Due to substantial changes in exposure during these time periods, crash frequency and crash rate behavior were examined through the appropriate models. For crash frequency behavior, traditional count-data models were considered. For crash rate behavior, a censored model was considered. In addition, temporal stability among contributing factors across regulatory periods was assessed by testing a hypothesis that factors affecting crash frequency and crash rate were consistent across time periods.

In addition to describing crash frequency behavior, injury severity behavior was examined using discrete choice methods to model injury severity across time periods. Temporal stability of contributing factors across time periods was also tested in the context of injury severity.

The final element of the freight safety behavior models consisted of holistic models that include indicators for the regulatory changes by time periods to determine the impact of that time period on crash frequency, crash rate, and injury severity.

3.3.1 Crash Frequency Models

For the crash frequency models, count-data models were used based on the nature of the dependent variable (i.e., crash frequency, which are non-negative integer values). A Poisson regression model is considered. In a Poisson model, the dependent variable y_i (crash frequency) is drawn from a Poisson population with parameter λ_i, where the Poisson model can be formulated as (Greene, 2018; Washington et al., 2020):

$$\boldsymbol{P(y_i) = \frac{e^{-\lambda_i}\lambda_i^{y_i}}{y_i!}} \quad \textbf{(3.6)}$$

where $P(y_i)$ is the probability of segment i having y_i crashes and λ_i is the Poisson parameter for segment i. The Poisson parameter is also equal to the expected number of crashes on segment i, E$[y_i]$. Poisson models are estimated by specifying the Poisson parameter as a function of explanatory variables such that (Greene, 2018; Washington et al., 2020):

$$\boldsymbol{\lambda_i = e^{\beta X_i}} \quad \textbf{(3.7)}$$

where $\boldsymbol{X}_i$ is a vector of explanatory variables and $\boldsymbol{\beta}$ is a vector of parameters to be estimated. Parameter estimates in the Poisson model are estimated using the following log-likelihood function (Greene, 2018; Washington et al., 2020):

$$\boldsymbol{LL(\beta) = \sum_{i=1}^{n}\left[-e^{\beta X_i} + y_i\beta X_i - \ln(y_i!)\right]} \quad \textbf{(3.8)}$$

To interpret the effect of a variable, marginal effects are used. Marginal effects are the effect of explanatory variable x_i on the dependent variable due to a one-unit increase in x_i. In the Poisson model, the Poisson parameter is the dependent variable (see Eq. (3.7)) such that marginal effects are computed as (Greene, 2018; Washington et al., 2020):

$$\boldsymbol{ME}_{\mathbf{X}_{ik}}^{\boldsymbol{\lambda}_i} = \frac{\partial \boldsymbol{\lambda}_i}{\partial \mathbf{X}_{ik}} = \boldsymbol{\beta}_k \boldsymbol{e}^{(\boldsymbol{\beta}\mathbf{X}_i)} \tag{3.9}$$

The Poisson model can be extended to account for unobserved heterogeneity by estimating random parameters. Estimating random parameters allows $\boldsymbol{\beta}$ to vary across observations (i.e., account for crash-specific variation) if a parameter is found to be randomly distributed. To estimate random parameters, parameters are now estimated as (Greene, 2018; Washington et al., 2020):

$$\boldsymbol{\beta}_n = \boldsymbol{\beta} + \boldsymbol{\varphi}_i \tag{3.10}$$

where $\boldsymbol{\beta}_n$ is a vector of parameters to be estimated that potentially vary across crash observations n, $\boldsymbol{\beta}$ is the vector of mean parameter estimates across all observations, and $\boldsymbol{\varphi}_i$ is a vector of randomly distributed terms. The Poisson parameter is now conditional on the vector of randomly distributed terms, such that $\lambda_i \mid \boldsymbol{\varphi}_i$. The log-likelihood function also changes and is now estimated through a simulation-based approach. When estimating parameters in this manner, both a mean and standard deviation are estimated. If the standard deviation is statistically significant, the estimated parameter is determined to be random. If the parameter is random, it will vary across crash observations based on a distribution specified by the analyst. For this work, the randomly distributed term is specified to be normally distributed.

Although a Poisson model will be estimated first, it has a key shortcoming: it cannot handle over- or under-dispersion. This is due to the Poisson model operating under the assumption that the mean and variance are equal, $\mathrm{E}[y_i] = \mathrm{Var}[y_i]$. If this equality is untrue, the data is said to be under-dispersed ($\mathrm{E}[y_i] > \mathrm{Var}[y_i]$) or over-dispersed ($\mathrm{E}[y_i] < \mathrm{Var}[y_i]$). If this occurs and is not corrected for, parameter estimates will no longer be unbiased and standard errors of the estimated parameters will be incorrect. To determine if this condition holds, there are several approaches.

One approach is to fit a Poisson model, determine the fitted values, determine the squared residuals, and identify the degrees of freedom. The analyst can sum the ratios of squared residuals and fitted values, then multiply by the inverse of the degrees of freedom based on n observations and $k + 1$ parameter estimates. If the value is 1, the Poisson conditions are met. If the value is significantly less than or greater than 1, an alternate modeling framework must be considered.

Another approach is to conduct a hypothesis test based on the assumption that under the Poisson model $(y_i - \mathrm{E}[y_i])^2 - \mathrm{E}[y_i]$ has a mean of zero, with $\mathrm{E}[y_i]$ being the predicted crash frequency $\hat{\lambda}_i$. The competing hypotheses are (Greene, 2018; Washington et al., 2020):

$$\boldsymbol{H_o}\text{: }\mathbf{Var}[\boldsymbol{y_i}] = \mathbf{E}[\boldsymbol{y_i}]$$

$$\boldsymbol{H_A}\text{: }\mathbf{Var}[\boldsymbol{y_i}] = \mathbf{E}[\boldsymbol{y_i}] + \boldsymbol{\alpha g}(\mathbf{E}[\boldsymbol{y_i}])$$

(3.11)

where $g(\mathrm{E}[y_i])$ is a function of the predicted crash frequency. To conduct the test, a simple linear regression model is estimated such that Z_i is regressed on W_i, where (Greene, 2018; Washington et al., 2020):

$$\boldsymbol{Z_i} = \frac{(\boldsymbol{y_i} - \mathbf{E}[\boldsymbol{y_i}])^2 - \boldsymbol{y_i}}{\mathbf{E}[\boldsymbol{y_i}]\sqrt{2}}$$

$$\boldsymbol{W_i} = \frac{\boldsymbol{g}(\mathbf{E}[\boldsymbol{y_i}])}{\sqrt{2}}$$

(3.12)

Based on the null hypothesis (i.e., equi-dispersion), the resulting test statistics have chi-square distributions with one degree of freedom. If the test statistics are greater than the chi-square critical value for one degree of freedom, the null hypothesis is rejected in favor of the alternative (i.e., dispersion is present). This test is done automatically when estimating a Poisson model in the software being used for this work.

Another approach consists of estimating a negative binomial model, where a key output of model specifications is the estimation of a dispersion parameter. If the dispersion parameter is statistically significant, there is evidence of dispersion and that a negative binomial model is preferred over a Poisson model. The former approach and this approach will be the tools used to assess dispersion in this work. If dispersion is present, a negative binomial model will be estimated.

It was determined that no significant dispersion was present for all crash frequency models; therefore, Poisson models were used and there was no need to estimate alternate types of count-data models.

3.3.2 Crash Rate Models

To model crash rate, the dependent variable must first be defined in terms of crash frequency per unit of exposure. In this work, the unit of exposure is one-million VMT. The dependent variable is determined by (Golembiewski and Chandler, 2011; Anderson and Hernandez, 2017a):

$$\boldsymbol{R_S} = \frac{\sum_{y=1}^{n} \boldsymbol{N_{ys}}}{\frac{\sum_{y=1}^{n} \mathbf{AADT}_{ys} \times \boldsymbol{L_s} \times \mathbf{365}}{\mathbf{1{,}000{,}000}}}$$

3.13)

where R_S is the number of crashes per million vehicles miles traveled (MVMT) on segment s, y denotes the time period, N_{ys} is the number of crashes in time period y on segment s, AADT_{ys} is the average annual daily traffic for time period y on segment s, and L_s is the length of segment s.

The nature of a crash rate dependent variable is continuous but can have clustering at lower or upper values (typically lower values at zero). Due to this, traditional linear regression models are not appropriate, and a censoring-based model should be applied. The Tobit model maintains the linear assumptions required for regression of a continuous dependent variable while also having the ability to censor as appropriate (Tobin, 1958).

The Tobit model is given as (Tobin, 1958):

$$\boldsymbol{y_s^* = \beta X_s + \varepsilon_s \ \text{ with } \varepsilon_s \sim N(0, \sigma^2) \text{ and } s = 1, 2, \dots, N} \tag{3.14}$$

with:

$$\boldsymbol{y_s = \begin{cases} y_s^* \text{ if } y_s^* > L \\ 0 \text{ if } y_s^* \leq L \end{cases}} \tag{3.15}$$

where y_s is the number of crashes per MVMT, L is the value at which the model if left-censored at, $\boldsymbol{X_s}$ is a vector of explanatory variables, $\boldsymbol{\beta}$ is a vector of parameters to be estimated, and ε_s is a normally and independently distributed error term with mean zero and constant variance σ^2. The corresponding likelihood function for the Tobit model is (Greene, 2018):

$$\boldsymbol{L = \prod_0 \left[1 - \Phi\left(\frac{\beta X_s}{\sigma}\right)\right] \prod_1 \sigma^{-1} \phi \left[\frac{(y_s - \beta X_s)}{\sigma}\right]} \tag{3.16}$$

where Φ is the standard normal distribution function and ϕ is the standard normal density function. To interpret parameter estimates, partial effects are computed such that (Greene, 2018):

$$\boldsymbol{\frac{\partial E[y \mid X]}{\partial X} = \beta \Phi \left(\frac{X\beta}{\sigma}\right)} \tag{3.17}$$

3.3.3 Injury Severity Models

For the injury severity models, four discrete injury severity outcomes were considered: (1) possible injury, (2) minor injury, (3) serious injury, and (4) fatal injury. Note that the no injury category was not included. This was due to the nature of Oregon crash data, as many crash characteristics are coded as NA for no injury crashes. This is discussed in further detail in Chapter 5.5.3.[5]

ue to there being four discrete outcomes, a discrete choice modeling framework was used. For this work, the multinomial logit model was used. The multinomial logit model allows for specification of a severity function for each severity, where the linear-in-parameters severity functions that describe the probability of an injury severity outcome takes the form (Train, 2009; Greene, 2018; Washington et al., 2020):

$$\boldsymbol{S_{in}} = \mathbf{X}_{\boldsymbol{in}}\boldsymbol{\beta_i} + \boldsymbol{\varepsilon_{in}} \tag{3.18}$$

where $\boldsymbol{\beta}_i$ is vector of estimated parameters for injury severity i, $\mathbf{X}_{in}$ is a vector of explanatory variables for crash n and injury severity i, and ε_{in} is a Type I Extreme Value distributed error term. When the error term is Type I Extreme Value distributed, it can be shown that the probability of injury severity i for crash n is given as (Train, 2009; Greene, 2018; Washington et al., 2020):

$$\boldsymbol{P_n(i)} = \frac{\boldsymbol{e}^{(\mathbf{X}_{\boldsymbol{in}}\boldsymbol{\beta_i})}}{\sum_{\boldsymbol{I}} \boldsymbol{e}^{(\mathbf{X}_{\boldsymbol{in}}\boldsymbol{\beta_i})}} \tag{3.19}$$

where Eq. (3.19) is the formulation of the standard multinomial logit model.

When estimating the injury severity models, unobserved heterogeneity is accounted for through the estimation of random parameters. When estimating random parameters, the multinomial logit model is given as (Train, 2009; Greene, 2018; Washington et al., 2020):

$$\boldsymbol{P_n(i \mid \varphi)} = \int \frac{\boldsymbol{e}^{(\mathbf{X}_{\boldsymbol{in}}\boldsymbol{\beta_i})}}{\sum_{\boldsymbol{I}} \boldsymbol{e}^{(\mathbf{X}_{\boldsymbol{in}}\boldsymbol{\beta_i})}} \boldsymbol{f(\beta \mid \varphi)}\, \mathbf{d}\boldsymbol{\beta} \tag{3.20}$$

where $P_n(i \mid \boldsymbol{\varphi})$ is the mixed logit probability, $f(\boldsymbol{\beta} \mid \boldsymbol{\varphi})$ is the density function of $\boldsymbol{\beta}$, and all other terms have been defined previously. The mixed logit probability is a weighted average of the logit probabilities with weights determined by the density function of $\boldsymbol{\beta}$. This process of weighting probabilities over several functions is considered a mixing function, where $f(\boldsymbol{\beta} \mid \boldsymbol{\varphi})$ is the mixing distribution. The addition of the density function to determine values of $\boldsymbol{\beta}$ now allows for model estimations to account for potential observation-specific variations of $\mathbf{X}$ on injury severity probabilities. A key component of the mixing distribution, which can take various forms, is to specify its distribution. For this work, the normal distribution is used.

[5] Models with no injury were estimated, but the large proportion of NA values for no injury crashes resulted in model stability and misspecification issues.

3.3.4 Model Goodness of Fit and Transferability

3.3.4.1 Model Goodness of Fit

To assess the goodness of fit for the crash frequency and injury severity models, McFadden's Pseudo R-squared value was used. This metric is computed as (Train, 2009; Greene, 2018; Washington et al., 2020):

$$\textbf{McFadden Pseudo } \boldsymbol{R^2} = \mathbf{1} - \frac{\boldsymbol{LL(\beta)}}{\boldsymbol{LL(0)}} \tag{3.21}$$

where $LL(\boldsymbol{\beta})$ is the log-likelihood at convergence with parameter vector $\boldsymbol{\beta}$ and $LL(0)$ is the log-likelihood at convergence with all parameters, except the constant(s), set to zero.

For the crash rate models, the Maddala Pseudo R-squared value was used to asses fit based on previous work (Veall and Zimmerman, 1996):

$$\textbf{Maddala Pseudo } \boldsymbol{R^2} = \mathbf{1} - \boldsymbol{e}^{\left(\frac{-2[\boldsymbol{LL(\beta)} - \boldsymbol{LL(0)}]}{\boldsymbol{N}}\right)} \tag{3.22}$$

where N is the number of observations and all other terms have been defined previously.

3.3.4.2 Parameter Transferability

In addition to a pooled model (a single model that has all time periods included), three disaggregate models were estimated for crash frequency, crash rate, and injury severity (one model for each time period). By applying this approach, a transferability test was conducted to determine if significant factors and parameter estimates are transferable across time periods (i.e., are the factors impacting crash frequency, crash rate, or injury severity different across the defined time periods). To accomplish this, a parameter transferability test was conducted through two different tests. The first test is (Washington et al., 2020):

$$\boldsymbol{\chi^2} = -\mathbf{2}\left[\boldsymbol{LL(\beta_P)} - \boldsymbol{LL(\beta_{T_1})} - \boldsymbol{LL(\beta_{T_2})} - \boldsymbol{LL(\beta_{T_3})}\right] \tag{3.23}$$

where $LL(\boldsymbol{\beta}_P)$ is the log-likelihood at convergence of the pooled model estimated with all time periods, $LL(\boldsymbol{\beta}_{T_1})$ is the log-likelihood at convergence of the pre-COVID time period model, $LL(\boldsymbol{\beta}_{T_2})$ is the log-likelihood at convergence of the COVID relaxation period with low exposure model, and $LL(\boldsymbol{\beta}_{T_3})$ is the log-likelihood at convergence of the COVID relaxation period with back-to-normal exposure model. The χ^2 statistics are chi-square distributed with degrees of freedom equal to the summation of the number of estimated parameters in all time period models minus the number of estimated parameters in the pooled model. If χ^2 from Eq. (3.23) exceeds the critical value of the chi-square statistic for the given degrees of freedom, the null hypothesis that parameters are the same across models is rejected in favor of the alternative (parameters are different).

The second test is a more comprehensive transferability test that when combined with the test in Eq. (3.23) provides very strong evidence that crash factors are different across time periods. This test is conducted as (Washington et al., 2020):

$$\boldsymbol{\chi^2 = -2\left[LL\left(\beta_{T_{ab}}\right) - LL\left(\beta_{T_a}\right)\right]} \tag{3.24}$$

where $LL\left(\boldsymbol{\beta}_{T_{ab}}\right)$ is the log-likelihood at convergence of a model using the parameters from time period b on time period a data and $LL\left(\boldsymbol{\beta}_{T_a}\right)$ is the log-likelihood at convergence of the time period a model. This is done for each pair of models and in both directions, thus creating a matrix of chi-square statistics and degrees of freedom to assess transferability. The chi-square statistic has degrees of freedom equal to the number of estimated parameters in $\boldsymbol{\beta}_{T_{ab}}$, where the null hypothesis that parameters are transferable is rejected if the result from Eq. (3.24) is greater than the critical chi-square statistics for a given degrees of freedom.

To provide an example, the best fit model for the COVID relaxation period with low exposure provides parameter estimates ($\boldsymbol{\beta}$). The parameter estimates from this model are then fixed (constants given starting values based on the estimates) and the same COVID relaxation period with low exposure model is fit using data from the pre-COVID model. This process is done in each direction with each model to create the matrix described previously.

4.0 RESULTS

The following chapter summarizes the results from the analyses conducted.

4.1 DESCRIPTIVE ANALYSIS RESULTS

The descriptive analysis results are presented through crash frequency and proportion tables, and results from the z-tests of proportions. For the plots, a particular category within a crash characteristic may have had more overall observations (the bar extends further on the plot), but it may have accounted for a smaller proportion of the total frequency compared to another category or time period (the percentage will be less). The plots are presented this way to compare both frequency and proportion across time periods directly, in addition to coinciding with the proportions provided in the proportions test tables. These plots are provided for both all crashes and only fatal and suspected serios injury crashes. Note that the fatal and suspected injury crash plots consider the proportion relative to all crashes.

In the proportions test tables, statistical significance is denoted by bold p-values (also referenced in the table footnotes).

The discussion for the descriptive analysis results is done by crash factor.

The supplemental descriptive analyses can be viewed in the Appendices of this report.

4.1.1 Driver Age

Figure 4.1 shows the proportion and frequency of truck-involved crashes by truck driver age and time period and Figure 4.2 shows the proportion and frequency of truck-involved crashes by truck driver age, time period, and highest sustained injury severity. Table 4.1 and Table 4.2 present the results of the z-tests of proportions, respectively. Considering all crashes, there is only one significant difference in proportions: the 35 years to 44 years age group between the pre-COVID period and the low VMT COVID relaxations period, where the proportion in the low VMT COVID relaxations period is significantly lower. The proportion of truck drivers aged 35 years to 44 years was also lower in the normal VMT COVID relaxations period but was just beyond the significance threshold (significant with 90% confidence); this was also true for the 65 years to 74 years age group, where there was a lower proportion in the normal VMT COVID relaxations period compared to the low VMT COVID relaxations period.

No significant difference in proportions is present when considering only fatal and suspected serious injury crashes. However, there was a difference that met a lower significance threshold (90%). For the 45 years to 54 years age group, there was a higher proportion of fatal and suspected injury crashes in the normal VMT COVID relaxations period compared to the low VMT COVID relaxations period.

Note the large number of unknown observations in Figure 4.1 and Table 4.1; this is due to driver age being coded as unknown for any no injury crash.

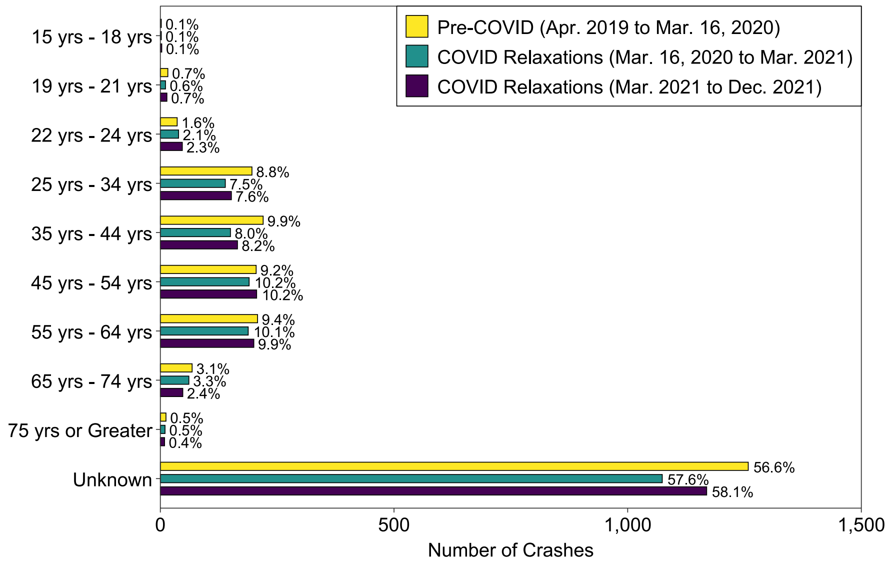

Figure 4.1: Frequency and Proportion of Truck-Involved Crashes by Truck Driver Age and Time Period

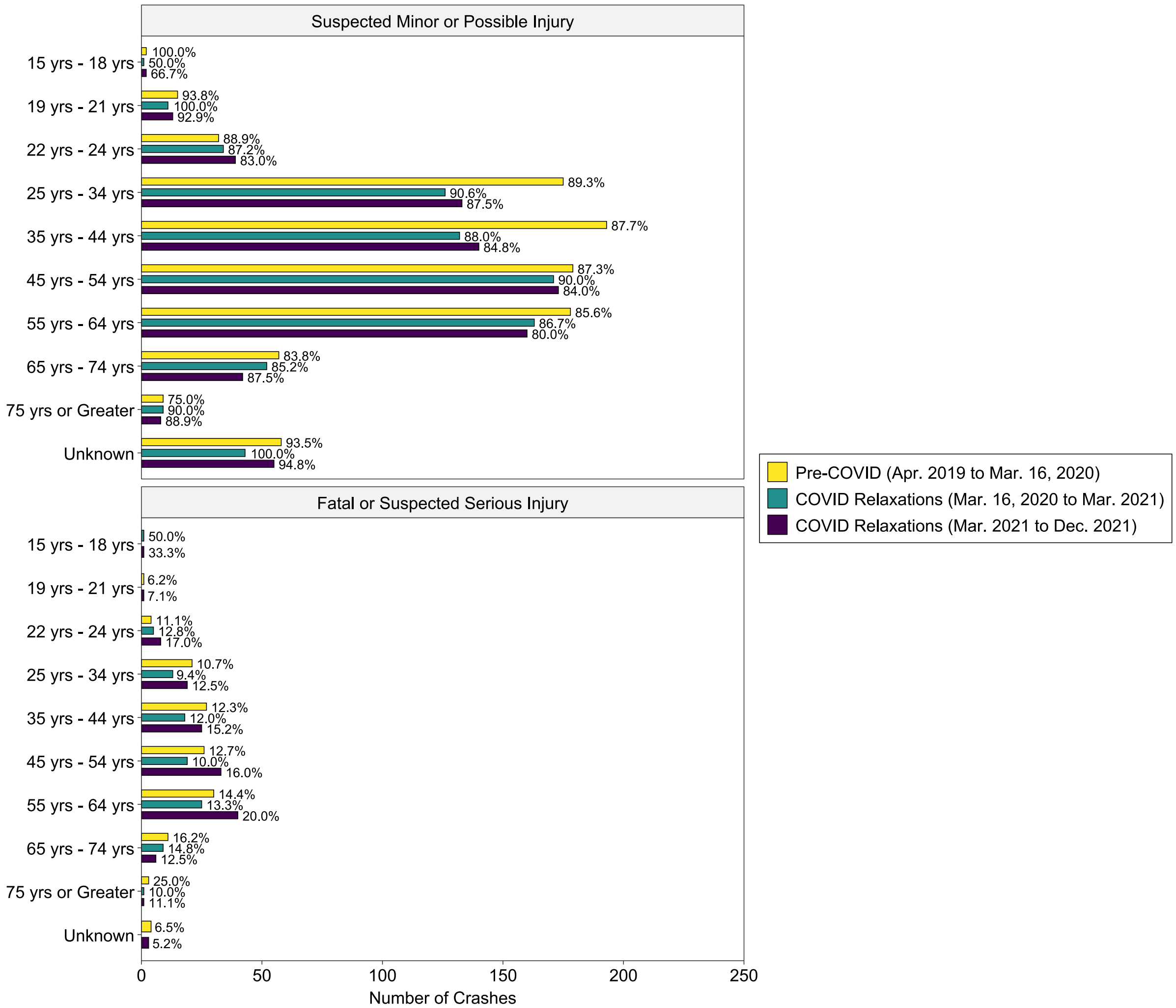

Figure 4.2: Frequency and Proportion of Truck-Involved Crashes by Truck Driver Age, Time Period, and Highest Sustained Injury Severity

Table 4.1: Test for Equality of Proportions of Truck-Involved Crashes by Truck Driver Age and Time Period

Driver Age	Pre-COVID (Apr. 2019 - Mar. 16, 2020)		COVID Relaxations (Low VMT) (Mar. 16, 2020 - Mar. 2021)		COVID Relaxations (Normal VMT) (Mar. 2021 - Dec. 2021)		*p*-value[1]	*p*-value[2]	*p*-value[3]
	Frequency	Proportion of Total	Frequency	Proportion of Total	Frequency	Proportion of Total			
15 yrs - 18 yrs	2	0.09%	2	0.11%	3	0.15%	0.861	0.577	0.718
19 yrs - 21 yrs	16	0.72%	11	0.59%	14	0.70%	0.609	0.923	0.682
22 yrs - 24 yrs	36	1.62%	39	2.09%	47	2.33%	0.264	0.094	0.608
25 yrs - 34 yrs	196	8.82%	139	7.46%	152	7.55%	0.113	0.132	0.912
35 yrs - 44 yrs	220	9.91%	150	8.05%	165	8.20%	**0.039**[a]	0.053	0.865
45 yrs - 54 yrs	205	9.23%	190	10.19%	206	10.23%	0.300	0.271	0.967
55 yrs - 64 yrs	208	9.37%	188	10.09%	200	9.94%	0.438	0.530	0.876
65 yrs - 74 yrs	68	3.06%	61	3.27%	48	2.38%	0.701	0.178	0.095
75 yrs or Greater	12	0.54%	10	0.54%	9	0.45%	0.987	0.666	0.690
Unknown	1,258	56.64%	1,074	57.62%	1,169	58.07%	0.530	0.347	0.775
Total	2,221	100%	1,864	100%	2,013	100%			

[1] Comparison between Pre-COVID (Apr. 2019 - Mar. 16, 2020) and COVID Relaxations (Mar. 16, 2020 - Mar. 2021)
[2] Comparison between Pre-COVID (Apr. 2019 - Mar. 16, 2020) and COVID Relaxations (Mar. 2021 - Dec. 2021)
[3] Comparison between COVID Relaxations (Mar. 16, 2020 - Mar. 2021) and COVID Relaxations (Mar. 2021 - Dec. 2021)
[a] Significant with at least 95% confidence

Table 4.2: Test for Equality of Proportions of Fatal and Suspected Serious Injury Truck-Involved Crashes by Truck Driver Age and Time Period

Driver Age	Pre-COVID (Apr. 2019 - Mar. 16, 2020)		COVID Relaxations (Low VMT) (Mar. 16, 2020 - Mar. 2021)		COVID Relaxations (Normal VMT) (Mar. 2021 - Dec. 2021)		*p*-value[1]	*p*-value[2]	*p*-value[3]
	Frequency	Proportion of Total	Frequency	Proportion of Total	Frequency	Proportion of Total			
15 yrs - 18 yrs	0	0.00%	1	0.05%	1	0.05%	0.275	0.293	0.957
19 yrs - 21 yrs	1	0.05%	0	0.00%	1	0.05%	0.360	0.945	0.336
22 yrs - 24 yrs	4	0.18%	5	0.27%	8	0.40%	0.550	0.184	0.487
25 yrs - 34 yrs	21	0.95%	13	0.70%	19	0.94%	0.385	0.996	0.397
35 yrs - 44 yrs	27	1.22%	18	0.97%	25	1.24%	0.446	0.938	0.412
45 yrs - 54 yrs	26	1.17%	19	1.02%	33	1.64%	0.644	0.194	0.094
55 yrs - 64 yrs	30	1.35%	25	1.34%	40	1.99%	0.979	0.105	0.118
65 yrs - 74 yrs	11	0.50%	9	0.48%	6	0.30%	0.955	0.311	0.354
75 yrs or Greater	3	0.14%	1	0.05%	1	0.05%	0.407	0.366	0.957
Unknown	4	0.18%	0	0.00%	3	0.15%	0.067	0.804	0.095
Total	127	6%	91	5%	137	7%			

[1] Comparison between Pre-COVID (Apr. 2019 - Mar. 16, 2020) and COVID Relaxations (Mar. 16, 2020 - Mar. 2021)

[2] Comparison between Pre-COVID (Apr. 2019 - Mar. 16, 2020) and COVID Relaxations (Mar. 2021 - Dec. 2021)

[3] Comparison between COVID Relaxations (Mar. 16, 2020 - Mar. 2021) and COVID Relaxations (Mar. 2021 - Dec. 2021)

[a] Significant with at least 95% confidence

4.1.2 Truck Driver-Level Crash Cause

Figure 4.3 shows the proportion and frequency of truck-involved crashes by truck driver-level crash cause and time period, and Figure 4.4 shows the proportion and frequency of truck-involved crashes by truck driver-level crash cause, time period, and highest sustained injury severity. Table 4.3 and Table 4.4 present the results of the z-tests of proportions, respectively.

Considering all crashes, there are significant differences in proportions for the truck driver not yielding the right-of-way between the pre-COVID period and the low VMT COVID relaxations period, as well as the pre-COIVD period and normal VMT COVID relaxations period. For both significant differences, the proportion of crashes due to truck drivers not yielding the right-of-way were lower in the COVID relaxations periods.

Significant differences are also present for failing to avoid the vehicle ahead, where the proportion of crashes in the low VMT COVID relaxations period was significantly lower than the proportion of crashes in the pre-COVID period. The proportion of crashes in the low VMT COVID relaxations period was also significantly lower than the proportion in the normal VMT COVID relaxations period.

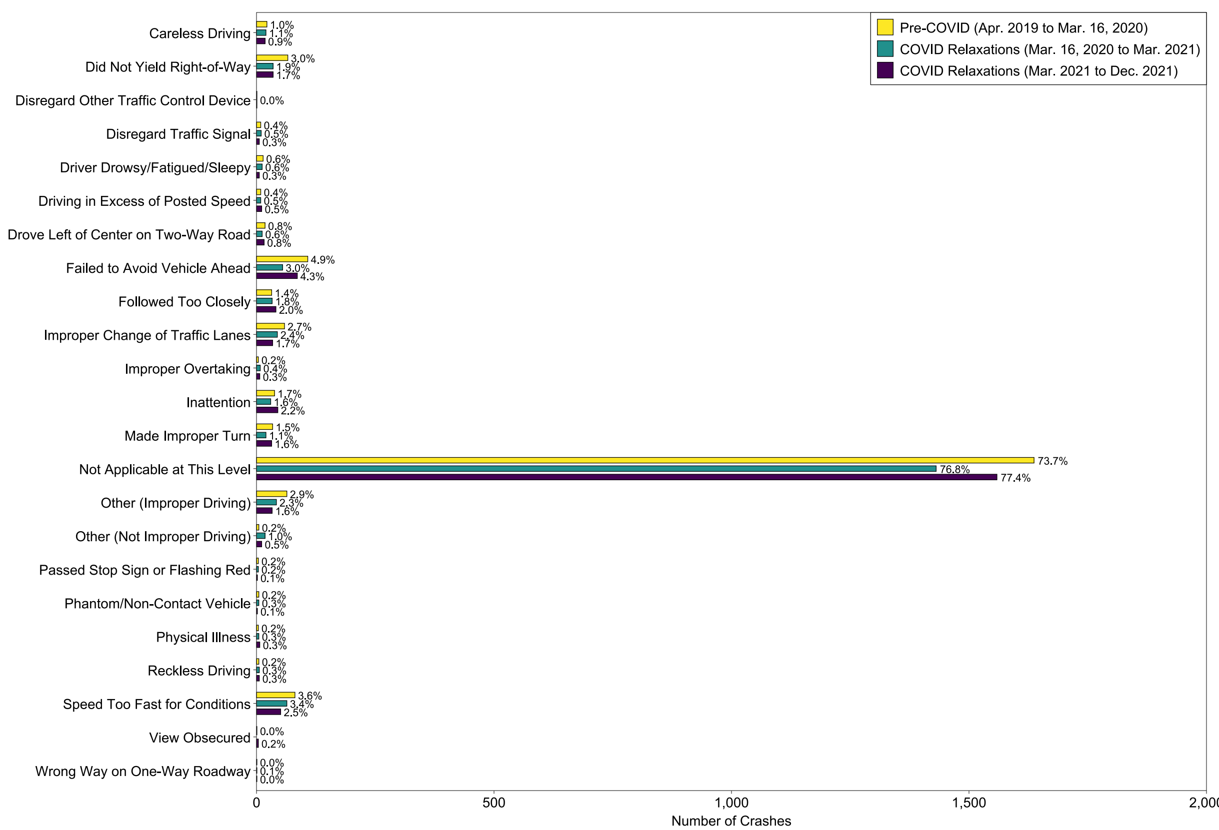

Figure 4.3: Frequency and Proportion of Truck-Involved Crashes by Truck Driver-Level Crash Cause and Time Period

For improper change of traffic lanes, the proportion of crashes in the normal VMT COVID relaxations period was significantly lower than the proportion of crashes in the pre-COVID period, as was the proportion for speed too fast for conditions. Crashes that occurred due to speed too fast for conditions also had a lower proportion of crashes in the normal VMT COVID relaxations period compared to the low VMT COIVD relaxations period (at a lower significance threshold).

Crashes that occurred due to the truck driver's view being obscured had a difference in proportions just beyond the significance threshold (90%), where the proportion of such crashes were higher in the normal VMT COVID relaxations period compared to the low VMT COVID relaxations period. There were also differences in the other-type categories.

Note the large number of not applicable at this level observations in Figure 4.3 and Table 4.3; this is due to driver-level crash cause being coded as not applicable at this level for any no injury crash.

When considering only fatal and suspected serious injury crashes, inattention had a singificantly higher proportion in the normal VMT COVID relaxations period compared to the low VMT COVID relaxations period. Although at a lower significance level (90%), the proportion of crashes due to inattention was lower in the low VMT COVID relaxations period compared to the pre-COVID period.

Speed too fast for conditions had a significantly lower proportion in the normal VMT COVID relaxations period compared to the low VMT COVID relaxations period, as well as the normal VMT COVID relaxations period compared to the pre-COVID period.

One additional truck driver-level crash cause that was significant at a lower threshold (90%) was driving in excess of the posted speed limit, where the proportion of crashes in the normal VMT COVID relaxations period was higher compared to the low VMT COVID relaxations period.

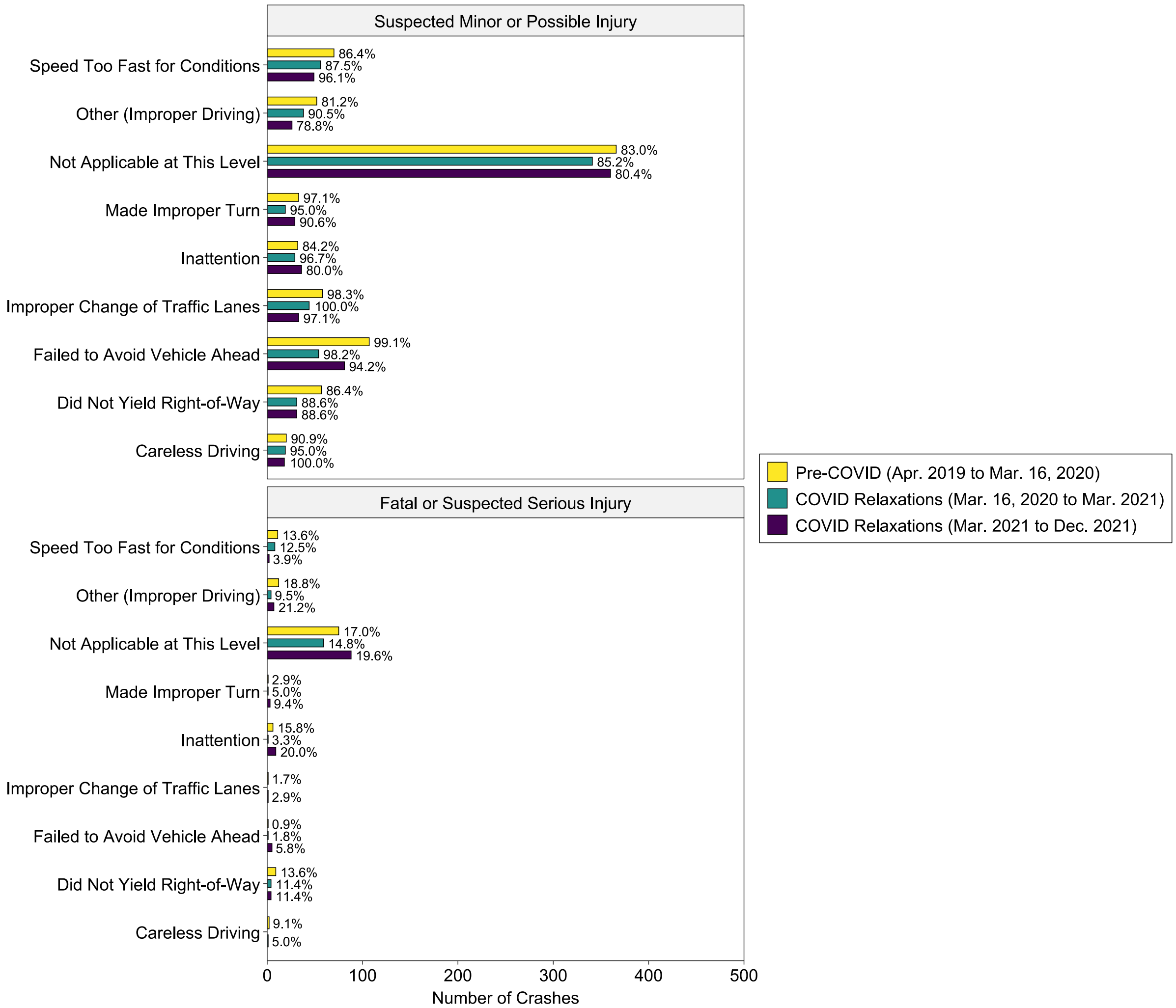

Figure 4.4: Frequency and Proportion of Truck-Involved Crashes by Truck Driver-Level Crash Cause (Most Occurring), Time Period, and Highest Sustained Injury Severity

Table 4.3: Test for Equality of Proportions of Truck-Involved Crashes by Truck Driver-Level Crash Cause and Time Period

Crash Cause	Pre-COVID (Apr. 2019 - Mar. 16, 2020)		COVID Relaxations (Low VMT) (Mar. 16, 2020 - Mar. 2021)		COVID Relaxations (Normal VMT) (Mar. 2021 - Dec. 2021)		*p*-value[1]	*p*-value[2]	*p*-value[3]
	Frequency	Proportion of Total	Frequency	Proportion of Total	Frequency	Proportion of Total			
Careless Driving	22	0.99%	20	1.07%	18	0.89%	0.795	0.746	0.572
Did Not Yield Right-of-Way	66	2.97%	35	1.88%	35	1.74%	**0.025[a]**	**0.009[a]**	0.745
Disregard Other Traffic Control Device	1	0.05%	0	0.00%	0	0.00%	0.360	0.341	NA
Disregard Traffic Signal	9	0.41%	10	0.54%	6	0.30%	0.539	0.558	0.247
Driver Drowsy/Fatigued/Sleepy	14	0.63%	12	0.64%	6	0.30%	0.957	0.115	0.114
Driving in Excess of Posted Speed	9	0.41%	9	0.48%	11	0.55%	0.709	0.503	0.782
Drove Left of Center on Two-Way Road	18	0.81%	12	0.64%	16	0.79%	0.534	0.955	0.579
Failed to Avoid Vehicle Ahead	108	4.86%	55	2.95%	86	4.27%	**0.002[a]**	0.359	**0.028[a]**
Followed Too Closely	32	1.44%	33	1.77%	41	2.04%	0.402	0.137	0.545
Improper Change of Traffic Lanes	59	2.66%	44	2.36%	34	1.69%	0.548	**0.032[a]**	0.137
Improper Overtaking	4	0.18%	8	0.43%	7	0.35%	0.143	0.285	0.683
Inattention	38	1.71%	30	1.61%	45	2.24%	0.801	0.219	0.157
Made Improper Turn	34	1.53%	20	1.07%	32	1.59%	0.202	0.877	0.162
Not Applicable at This Level	1,637	73.71%	1,431	76.77%	1,559	77.45%	**0.024[a]**	**0.005[a]**	0.617
Other (Improper Driving)	64	2.88%	42	2.25%	33	1.64%	0.208	**0.007**	0.166
Other (Not Improper Driving)	5	0.23%	18	0.97%	11	0.55%	**0.002[a]**	0.089	0.130

Crash Cause	Pre-COVID (Apr. 2019 - Mar. 16, 2020)		COVID Relaxations (Low VMT) (Mar. 16, 2020 - Mar. 2021)		COVID Relaxations (Normal VMT) (Mar. 2021 - Dec. 2021)		*p*-value[1]	*p*-value[2]	*p*-value[3]
	Frequency	Proportion of Total	Frequency	Proportion of Total	Frequency	Proportion of Total			
Passed Stop Sign or Flashing Red	4	0.18%	4	0.21%	2	0.10%	0.804	0.485	0.362
Phantom/Non-Contact Vehicle	5	0.23%	5	0.27%	2	0.10%	0.781	0.314	0.216
Physical Illness	4	0.18%	5	0.27%	7	0.35%	0.550	0.285	0.656
Reckless Driving	5	0.23%	6	0.32%	6	0.30%	0.552	0.641	0.894
Speed Too Fast for Conditions	81	3.65%	64	3.43%	51	2.53%	0.713	**0.037**[a]	0.099
View Obscured	1	0.05%	0	0.00%	4	0.20%	0.360	0.146	0.054
Wrong Way on One-Way Roadway	1	0.05%	1	0.05%	1	0.05%	0.901	0.945	0.957
Total	2,221	100%	1,864	100%	2,013	100%			

[1] Comparison between Pre-COVID (Apr. 2019 - Mar. 16, 2020) and COVID Relaxations (Mar. 16, 2020 - Mar. 2021)

[2] Comparison between Pre-COVID (Apr. 2019 - Mar. 16, 2020) and COVID Relaxations (Mar. 2021 - Dec. 2021)

[3] Comparison between COVID Relaxations (Mar. 16, 2020 - Mar. 2021) and COVID Relaxations (Mar. 2021 - Dec. 2021)

[a] Significant with at least 95% confidence

[1] Comparison between Pre-COVID (Apr. 2019 - Mar. 16, 2020) and COVID Relaxations (Mar. 16, 2020 - Mar. 2021)

[2] Comparison between Pre-COVID (Apr. 2019 - Mar. 16, 2020) and COVID Relaxations (Mar. 2021 - Dec. 2021)

[3] Comparison between COVID Relaxations (Mar. 16, 2020 - Mar. 2021) and COVID Relaxations (Mar. 2021 - Dec. 2021)

[a] Significant with at least 95% confidence

Table 4.4: Test for Equality of Proportions of Fatal and Suspected Serious Injury Truck-Involved Crashes by Truck Driver-Level Crash Cause and Time Period

Crash Cause	Pre-COVID (Apr. 2019 - Mar. 16, 2020)		COVID Relaxations (Low VMT) (Mar. 16, 2020 - Mar. 2021)		COVID Relaxations (Normal VMT) (Mar. 2021 - Dec. 2021)		*p*-value[1]	*p*-value[2]	*p*-value[3]
	Frequency	Proportion of Total	Frequency	Proportion of Total	Frequency	Proportion of Total			
Careless Driving	2	0.09%	1	0.05%	0	0.00%	0.669	0.178	0.299
Did Not Yield Right-of-Way	9	0.41%	4	0.21%	4	0.20%	0.281	0.225	0.913
Disregard Traffic Signal	1	0.05%	0	0.00%	2	0.10%	0.360	0.507	0.173
Driver Drowsy/Fatigued/Sleepy	1	0.05%	1	0.05%	0	0.00%	0.901	0.341	0.299
Driving in Excess of Posted Speed	2	0.09%	0	0.00%	3	0.15%	0.195	0.577	0.095
Drove Left of Center on Two-Way Road	1	0.05%	1	0.05%	2	0.10%	0.901	0.507	0.609
Failed to Avoid Vehicle Ahead	1	0.05%	1	0.05%	5	0.25%	0.901	0.079	0.123
Followed Too Closely	1	0.05%	4	0.21%	5	0.25%	0.123	0.079	0.827
Improper Change of Traffic Lanes	1	0.05%	0	0.00%	1	0.05%	0.360	0.945	0.336
Inattention	6	0.27%	1	0.05%	9	0.45%	0.096	0.333	**0.016**[a]
Made Improper Turn	1	0.05%	1	0.05%	3	0.15%	0.901	0.271	0.355
Not Applicable at This Level	75	3.38%	59	3.17%	88	4.37%	0.705	0.093	**0.049**[a]
Other (Improper Driving)	12	0.54%	4	0.21%	7	0.35%	0.097	0.349	0.436
Other (Not Improper Driving)	0	0.00%	2	0.11%	3	0.15%	0.123	0.069	0.718
Passed Stop Sign or Flashing Red	0	0.00%	1	0.05%	1	0.05%	0.275	0.293	0.957
Phantom/Non-Contact Vehicle	1	0.05%	0	0.00%	0	0.00%	0.360	0.341	NA

Crash Cause	Pre-COVID (Apr. 2019 - Mar. 16, 2020)		COVID Relaxations (Low VMT) (Mar. 16, 2020 - Mar. 2021)		COVID Relaxations (Normal VMT) (Mar. 2021 - Dec. 2021)		*p*-value[1]	*p*-value[2]	*p*-value[3]
	Frequency	Proportion of Total	Frequency	Proportion of Total	Frequency	Proportion of Total			
Physical Illness	0	0.00%	2	0.11%	1	0.05%	0.123	0.293	0.519
Reckless Driving	2	0.09%	1	0.05%	1	0.05%	0.669	0.622	0.957
Speed Too Fast for Conditions	11	0.50%	8	0.43%	2	0.10%	0.757	**0.020**[a]	**0.043**[a]
Total	127	6%	91	5%	137	7%			

[1] Comparison between Pre-COVID (Apr. 2019 - Mar. 16, 2020) and COVID Relaxations (Mar. 16, 2020 - Mar. 2021)
[2] Comparison between Pre-COVID (Apr. 2019 - Mar. 16, 2020) and COVID Relaxations (Mar. 2021 - Dec. 2021)
[3] Comparison between COVID Relaxations (Mar. 16, 2020 - Mar. 2021) and COVID Relaxations (Mar. 2021 - Dec. 2021)
[a] Significant with at least 95% confidence

4.1.3 Collision Type

Figure 4.5 shows the proportion and frequency of truck-involved crashes by collision type and time period and Figure 4.6 shows the proportion and frequency of truck-involved crashes by collision type, time period, and highest sustained injury severity. Table 4.5 and Table 4.6 present the results of the z-tests of proportions, respectively.

Considering all crashes, the proportion of sideswipe (overtaking) truck-involved crashes was significantly lower in the low VMT COVID relaxations period compared to the pre-COVID period. Collisions with parked vehicles had significantly lower proportions in the low and normal VMT COVID relaxations periods compared to the pre-COVID period. Lastly, fixed-object crashes had a significantly higher proportion in the low VMT COVID relaxations period compared to the pre-COVID period and a significantly higher proportion compared to the normal VMT COVID relaxations period.

There were also differences in proportions with a lower significance threshold (90%). The proportion of rear-end crashes had a higher proportion in the normal VMT COVID relaxations period compared to the low VMT COVID relaxations period. The proportion of sideswipe (meeting) crashes had a higher proportion in the low VMT COVID relaxations period compared to the pre-COVID period and compared to the normal VMT COVID relaxations period.

Considering only fatal and suspected serious injury truck-involved crashes, there were no significant differences in proportions that met the 95% threshold. There were, however, differences that met a lower significance threshold (90%). The proportion of fatal and suspected injury angle crashes was higher in the normal VMT COVID relaxations period compared to the low COVID relaxations period and the pre-COVID period. Additionally, the proportion of fatal and suspected serious injury sideswipe (overtaking) crashes was lower in the low VMT COVID relaxations period compared to the pre-COVID period.

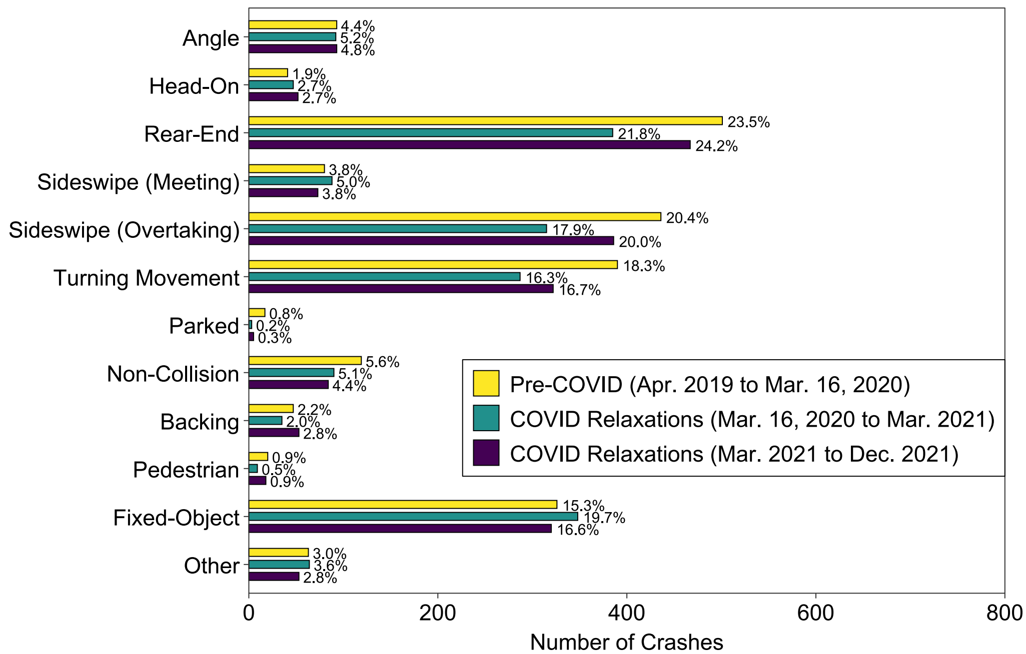

Figure 4.5: Frequency and Proportion of Truck-Involved Crashes by Collision Type and Time Period

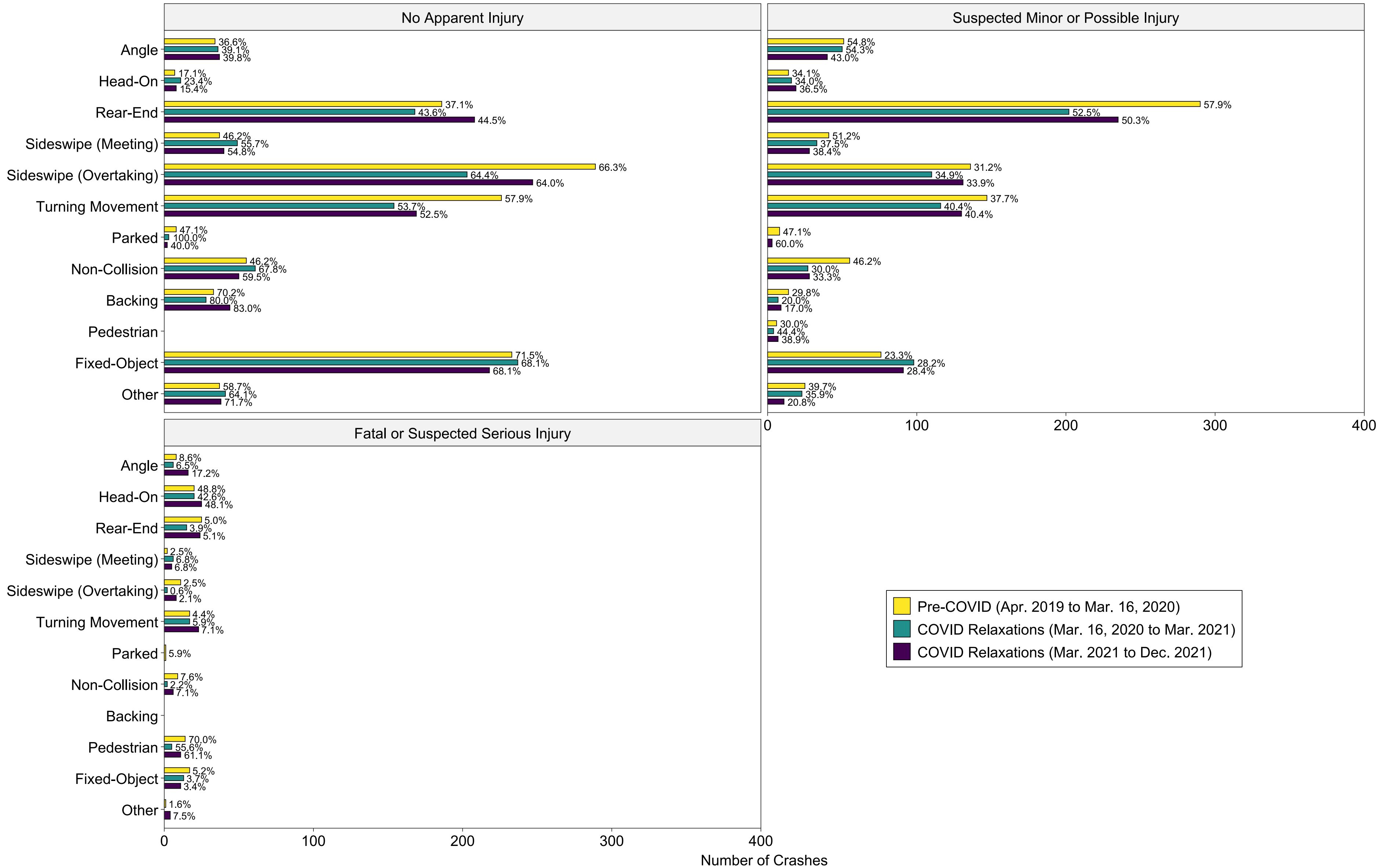

Figure 4.6: Frequency and Proportion of Truck-Involved Crashes by Collision Type, Time Period, and Highest Sustained Injury Severity

Table 4.5: Test for Equality of Proportions of Truck-Involved Crashes by Collision Type and Time Period

Collision Type	Pre-COVID (Apr. 2019 - Mar. 16, 2020)		COVID Relaxations (Low VMT) (Mar. 16, 2020 - Mar. 2021)		COVID Relaxations (Normal VMT) (Mar. 2021 - Dec. 2021)		*p*-value[1]	*p*-value[2]	*p*-value[3]
	Frequency	Proportion of Total	Frequency	Proportion of Total	Frequency	Proportion of Total			
Angle	93	4.36%	92	5.22%	93	4.83%	0.239	0.524	0.641
Head-On	41	1.92%	47	2.67%	52	2.70%	0.148	0.121	1.000
Rear-End	501	23.49%	385	21.84%	467	24.25%	0.236	0.596	0.090
Sideswipe (Meeting)	80	3.75%	88	4.99%	73	3.79%	0.069	1.000	0.089
Sideswipe (Overtaking)	436	20.44%	315	17.87%	386	20.04%	**0.047**[a]	0.782	0.101
Turning Movement	390	18.28%	287	16.28%	322	16.72%	0.109	0.205	0.753
Parked	17	0.80%	3	0.17%	5	0.26%	**0.012**[a]	**0.034**[a]	0.819
Non-Collision	119	5.58%	90	5.10%	84	4.36%	0.560	0.088	0.324
Backing	47	2.20%	35	1.99%	53	2.75%	0.719	0.306	0.157
Pedestrian	20	0.94%	9	0.51%	18	0.93%	0.175	1.000	0.188
Fixed-Object	326	15.28%	348	19.74%	320	16.61%	**0.000**[a]	0.265	**0.016**[a]
Other	63	2.95%	64	3.63%	53	2.75%	0.274	0.771	0.154
Total	2,133	100%	1,763	100%	1,926	100%			

[1] Comparison between Pre-COVID (Apr. 2019 - Mar. 16, 2020) and COVID Relaxations (Mar. 16, 2020 - Mar. 2021)
[2] Comparison between Pre-COVID (Apr. 2019 - Mar. 16, 2020) and COVID Relaxations (Mar. 2021 - Dec. 2021)
[3] Comparison between COVID Relaxations (Mar. 16, 2020 - Mar. 2021) and COVID Relaxations (Mar. 2021 - Dec. 2021)
[a] Significant with at least 95% confidence

Table 4.6: Test for Equality of Proportions of Fatal and Suspected Injury Truck-Involved Crashes by Collision Type and Time Period

Collision Type	Pre-COVID (Apr. 2019 - Mar. 16, 2020)		COVID Relaxations (Low VMT) (Mar. 16, 2020 - Mar. 2021)		COVID Relaxations (Normal VMT) (Mar. 2021 - Dec. 2021)		*p*-value[1]	*p*-value[2]	*p*-value[3]
	Frequency	Proportion of Total	Frequency	Proportion of Total	Frequency	Proportion of Total			
Angle	8	0.4%	6	0.3%	16	0.8%	1.000	0.092	0.086
Head-On	20	0.9%	20	1.1%	25	1.3%	0.655	0.345	0.763
Rear-End	25	1.2%	15	0.9%	24	1.2%	0.406	0.943	0.312
Sideswipe (Meeting)	2	0.1%	6	0.3%	5	0.3%	0.181	0.372	0.883
Sideswipe (Overtaking)	11	0.5%	2	0.1%	8	0.4%	0.059	0.812	0.149
Turning Movement	17	0.8%	17	1.0%	23	1.2%	0.700	0.263	0.607
Parked	1	0.0%	0	0.0%	0	0.0%	1.000	1.000	NA
Non-Collision	9	0.4%	2	0.1%	6	0.3%	0.133	0.749	0.348
Backing	0	0.0%	0	0.0%	0	0.0%	NA	NA	NA
Pedestrian	14	0.7%	5	0.3%	11	0.6%	0.152	0.884	0.282
Fixed-Object	17	0.8%	13	0.7%	11	0.6%	0.978	0.498	0.673
Other	1	0.0%	0	0.0%	4	0.2%	1.000	0.312	0.157
Total	125	6%	86	5%	133	7%			

[1] Comparison between Pre-COVID (Apr. 2019 - Mar. 16, 2020) and COVID Relaxations (Mar. 16, 2020 - Mar. 2021)

[2] Comparison between Pre-COVID (Apr. 2019 - Mar. 16, 2020) and COVID Relaxations (Mar. 2021 - Dec. 2021)

[3] Comparison between COVID Relaxations (Mar. 16, 2020 - Mar. 2021) and COVID Relaxations (Mar. 2021 - Dec. 2021)

[a] Significant with at least 95% confidence

4.1.4 Day of the Week

Figure 4.7 shows the proportion and frequency of truck-involved crashes by day of the week and time period and Figure 4.8 shows the proportion and frequency of truck-involved crashes by day of the week, time period, and highest sustained injury severity. Table 4.7 and Table 4.8 present the results of the z-tests of proportions, respectively.

There were no significant differences in proportions when considering all crashes or when considering only fatal and suspected serious injury crashes. There was a difference when considering fatal and suspected serious injury crashes that met a lower significance threshold (90%). Specifically, crashes that occurred on Thursday had a higher proportion in the normal VMT COVID relaxations period compared to the low VMT COVID relaxations period.

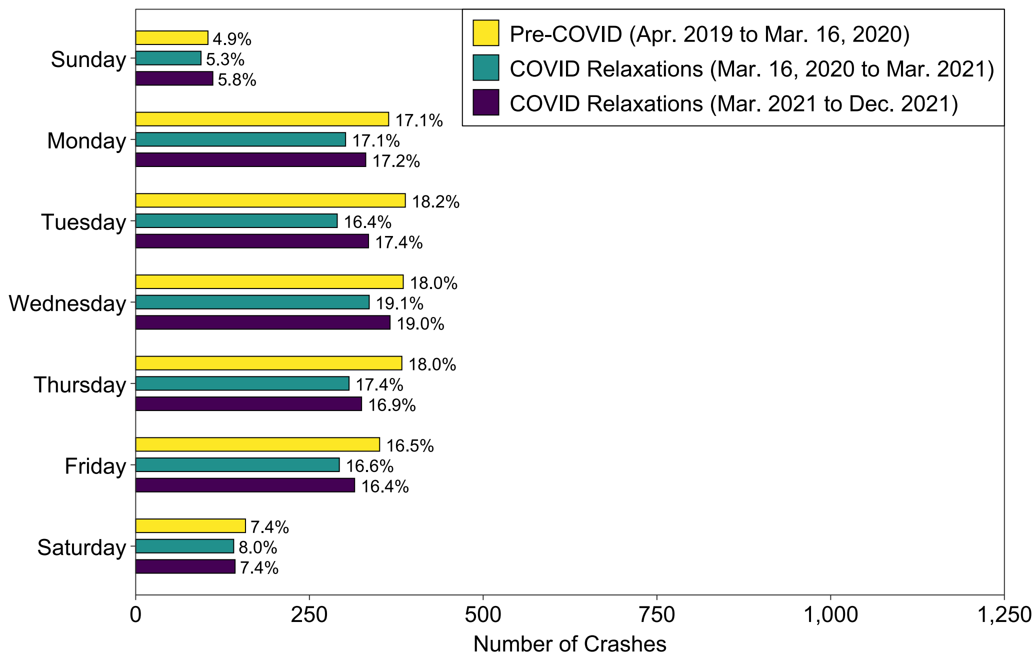

Figure 4.7: Frequency and Proportion of Truck-Involved Crashes by Day of the Week and Time Period

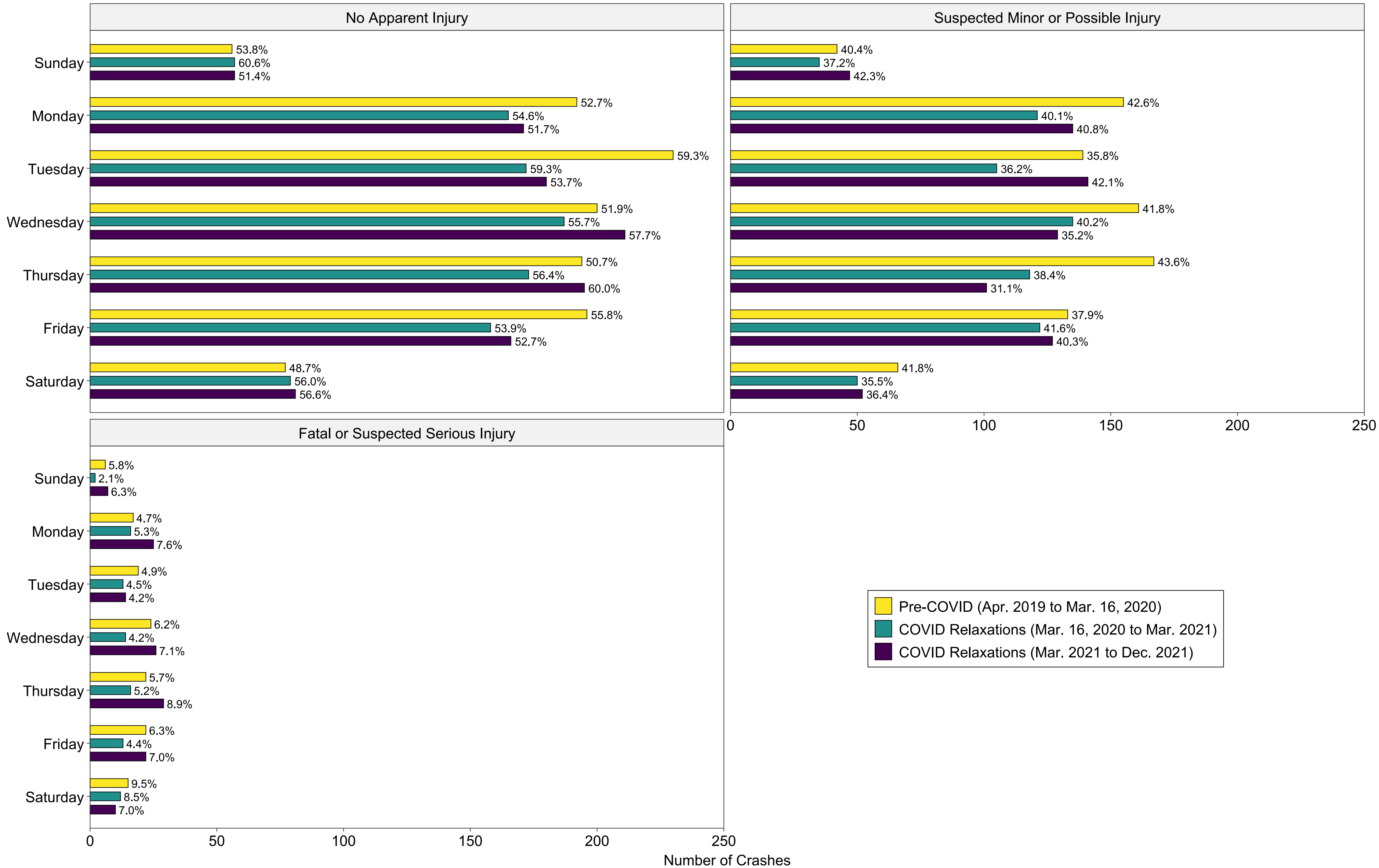

Figure 4.8: Frequency and Proportion of Truck-Involved Crashes by Day of the Week, Time Period, and Highest Sustained Injury Severity

Table 4.7: Test for Equality of Proportions of Truck-Involved Crashes by Day of the Week and Time Period

Day of the Week	Pre-COVID (Apr. 2019 - Mar. 16, 2020)		COVID Relaxations (Low VMT) (Mar. 16, 2020 - Mar. 2021)		COVID Relaxations (Normal VMT) (Mar. 2021 - Dec. 2021)		*p*-value[1]	*p*-value[2]	*p*-value[3]
	Frequency	Proportion of Total	Frequency	Proportion of Total	Frequency	Proportion of Total			
Sunday	104	4.9%	94	5.3%	111	5.8%	0.519	0.207	0.568
Monday	364	17.1%	302	17.1%	331	17.2%	0.957	0.919	0.964
Tuesday	388	18.2%	290	16.4%	335	17.4%	0.154	0.508	0.445
Wednesday	385	18.0%	336	19.1%	366	19.0%	0.420	0.435	0.966
Thursday	383	18.0%	307	17.4%	325	16.9%	0.659	0.365	0.664
Friday	351	16.5%	293	16.6%	315	16.4%	0.891	0.931	0.829
Saturday	158	7.4%	141	8.0%	143	7.4%	0.491	0.983	0.514
Total	2,133	100%	1,763	100%	1,926	100%			

[1] Comparison between Pre-COVID (Apr. 2019 - Mar. 16, 2020) and COVID Relaxations (Mar. 16, 2020 - Mar. 2021)

[2] Comparison between Pre-COVID (Apr. 2019 - Mar. 16, 2020) and COVID Relaxations (Mar. 2021 - Dec. 2021)

[3] Comparison between COVID Relaxations (Mar. 16, 2020 - Mar. 2021) and COVID Relaxations (Mar. 2021 - Dec. 2021)

[a] Significant with at least 95% confidence

Table 4.8: Test for Equality of Proportions of Fatal and Suspected Serious Injury Truck-Involved Crashes by Day of the Week and Time Period

Day of the Week	Pre-COVID (Apr. 2019 - Mar. 16, 2020)		COVID Relaxations (Low VMT) (Mar. 16, 2020 - Mar. 2021)		COVID Relaxations (Normal VMT) (Mar. 2021 - Dec. 2021)		*p*-value[1]	*p*-value[2]	*p*-value[3]
	Frequency	Proportion of Total	Frequency	Proportion of Total	Frequency	Proportion of Total			
Sunday	6	0.3%	2	0.1%	7	0.4%	0.249	0.644	0.124
Monday	17	0.8%	16	0.9%	25	1.3%	0.708	0.115	0.258
Tuesday	19	0.9%	13	0.7%	14	0.7%	0.598	0.562	0.970
Wednesday	24	1.1%	14	0.8%	26	1.3%	0.295	0.517	0.103
Thursday	22	1.0%	16	0.9%	29	1.5%	0.695	0.176	0.098
Friday	22	1.0%	13	0.7%	22	1.1%	0.333	0.733	0.205
Saturday	15	0.7%	12	0.7%	10	0.5%	0.933	0.454	0.525
Total	125	6%	86	5%	133	7%			

[1] Comparison between Pre-COVID (Apr. 2019 - Mar. 16, 2020) and COVID Relaxations (Mar. 16, 2020 - Mar. 2021)
[2] Comparison between Pre-COVID (Apr. 2019 - Mar. 16, 2020) and COVID Relaxations (Mar. 2021 - Dec. 2021)
[3] Comparison between COVID Relaxations (Mar. 16, 2020 - Mar. 2021) and COVID Relaxations (Mar. 2021 - Dec. 2021)
[a] Significant with at least 95% confidence

4.1.5 Driver Gender

Figure 4.9 shows the proportion and frequency of truck-involved crashes by truck driver gender and time period and Figure 4.10 shows the proportion and frequency of truck-involved crashes by truck driver gender, time period, and highest sustained injury severity. Table 4.9 and Table 4.10 present the results of the z-tests of proportions, respectively.

There were no significant differences in proportions when considering all crashes.

Considering only fatal and suspected serious injury crashes, there was a significantly higher proportion of male truck drivers in the normal VMT COVID relaxations period compared to the low VMT COVID relaxations period.

Note the large number of unknown observations in Figure 4.9 and Table 4.9Table 4.1; this is due to driver gender being coded as unknown for any no injury crash.

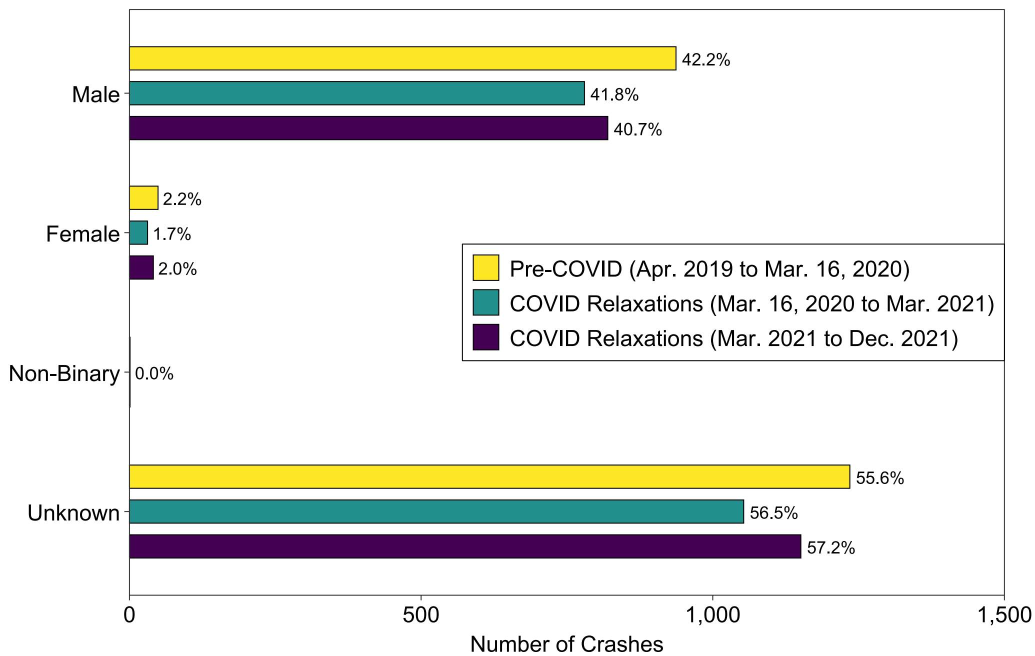

Figure 4.9: Frequency and Proportion of Truck-Involved Crashes by Truck Driver Gender and Time Period

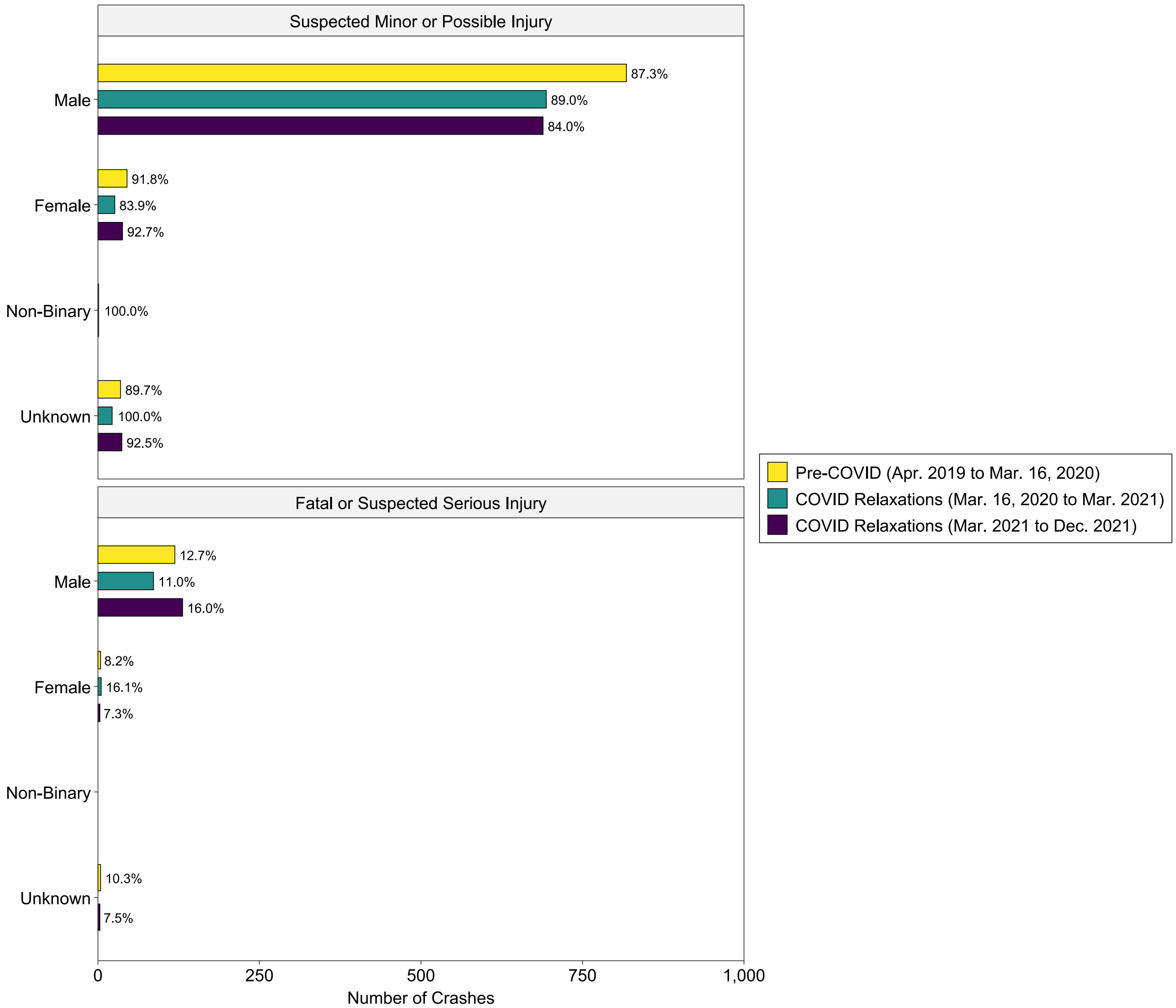

Figure 4.10: Frequency and Proportion of Truck-Involved Crashes by Truck Driver Gender, Time Period, and Highest Sustained Injury Severity

Table 4.9: Test for Equality of Proportions of Truck-Involved Crashes by Truck Driver Gender and Time Period

Gender	Pre-COVID (Apr. 2019 - Mar. 16, 2020)		COVID Relaxations (Low VMT) (Mar. 16, 2020 - Mar. 2021)		COVID Relaxations (Normal VMT) (Mar. 2021 - Dec. 2021)		*p*-value[1]	*p*-value[2]	*p*-value[3]
	Frequency	Proportion of Total	Frequency	Proportion of Total	Frequency	Proportion of Total			
Male	937	42.2%	780	41.8%	820	40.7%	0.825	0.338	0.483
Female	49	2.2%	31	1.7%	41	2.0%	0.212	0.703	0.389
Non-Binary	0	0.0%	0	0.0%	1	0.0%	NA	0.293	0.336
Unknown	1,235	55.6%	1,053	56.5%	1,151	57.2%	0.570	0.303	0.666
Total	2,221	100%	1,864	100%	2,013	100%			

[1] Comparison between Pre-COVID (Apr. 2019 - Mar. 16, 2020) and COVID Relaxations (Mar. 16, 2020 - Mar. 2021)
[2] Comparison between Pre-COVID (Apr. 2019 - Mar. 16, 2020) and COVID Relaxations (Mar. 2021 - Dec. 2021)
[3] Comparison between COVID Relaxations (Mar. 16, 2020 - Mar. 2021) and COVID Relaxations (Mar. 2021 - Dec. 2021)
[a] Significant with at least 95% confidence

Table 4.10: Test for Equality of Proportions of Fatal and Suspected Serious Injury Truck-Involved Crashes by Truck Driver Gender and Time Period

Gender	Pre-COVID (Apr. 2019 - Mar. 16, 2020)		COVID Relaxations (Low VMT) (Mar. 16, 2020 - Mar. 2021)		COVID Relaxations (Normal VMT) (Mar. 2021 - Dec. 2021)		*p*-value[1]	*p*-value[2]	*p*-value[3]
	Frequency	Proportion of Total	Frequency	Proportion of Total	Frequency	Proportion of Total			
Male	119	5.4%	86	4.6%	131	6.5%	0.278	0.113	**0.010**[a]
Female	4	0.2%	5	0.3%	3	0.1%	0.550	0.804	0.414
Unknown	4	0.2%	0	0.0%	3	0.1%	0.067	0.804	0.095
Total	127	6%	91	5%	137	7%			

[1] Comparison between Pre-COVID (Apr. 2019 - Mar. 16, 2020) and COVID Relaxations (Mar. 16, 2020 - Mar. 2021)
[2] Comparison between Pre-COVID (Apr. 2019 - Mar. 16, 2020) and COVID Relaxations (Mar. 2021 - Dec. 2021)
[3] Comparison between COVID Relaxations (Mar. 16, 2020 - Mar. 2021) and COVID Relaxations (Mar. 2021 - Dec. 2021)
[a] Significant with at least 95% confidence

4.1.6 Lighting Condition

Figure 4.11 shows the proportion and frequency of truck-involved crashes by lighting condition and time period and Figure 4.12 shows the proportion and frequency of truck-involved crashes by lighting condition, time period, and highest sustained injury severity. Table 4.11 and Table 4.12 present the results of the z-tests of proportions, respectively.

There were no significant differences in proportions when considering all crashes. There was, however, a difference in proportions that met a lower significance threshold (90%). The proportion of crashes that occurred at dusk were lower in the low VMT COVID relaxations period compared to the pre-COVID period.

Considering only fatal and suspected serious injury crashes, crashes that occurred at dark with no streetlights had a significantly lower proportion in the low VMT COVID relaxations period compared to the pre-COVID period.

At a lower significance threshold, the proportion of fatal and suspected serious injury crashes that occurred at dawn were higher in the normal VMT COVID relaxations period compared to the pre-COVID period.

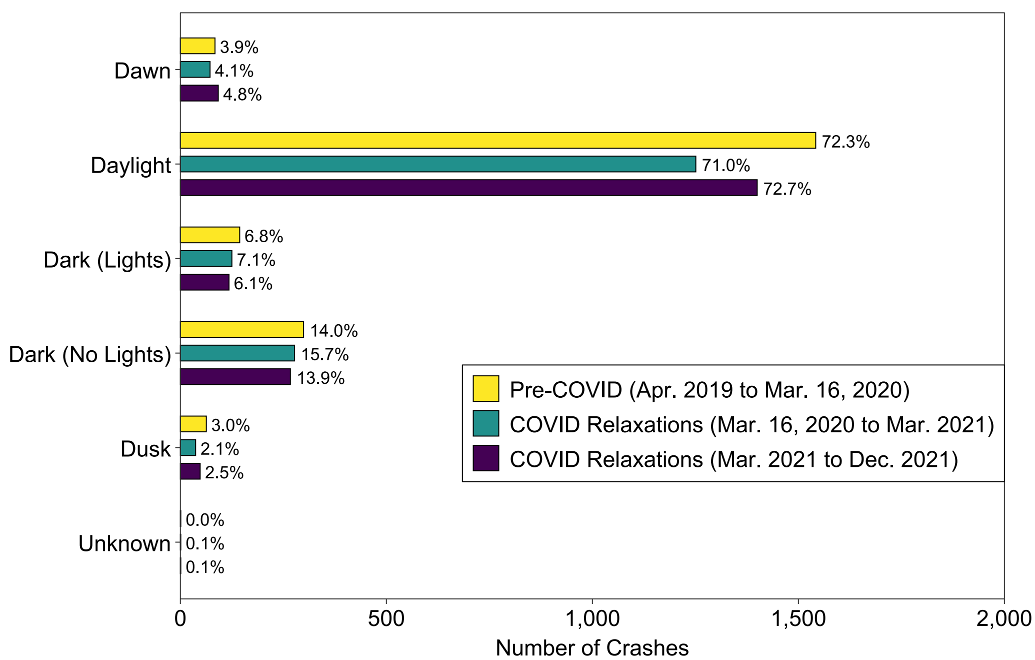

Figure 4.11: Frequency and Proportion of Truck-Involved Crashes by Lighting Condition and Time Period

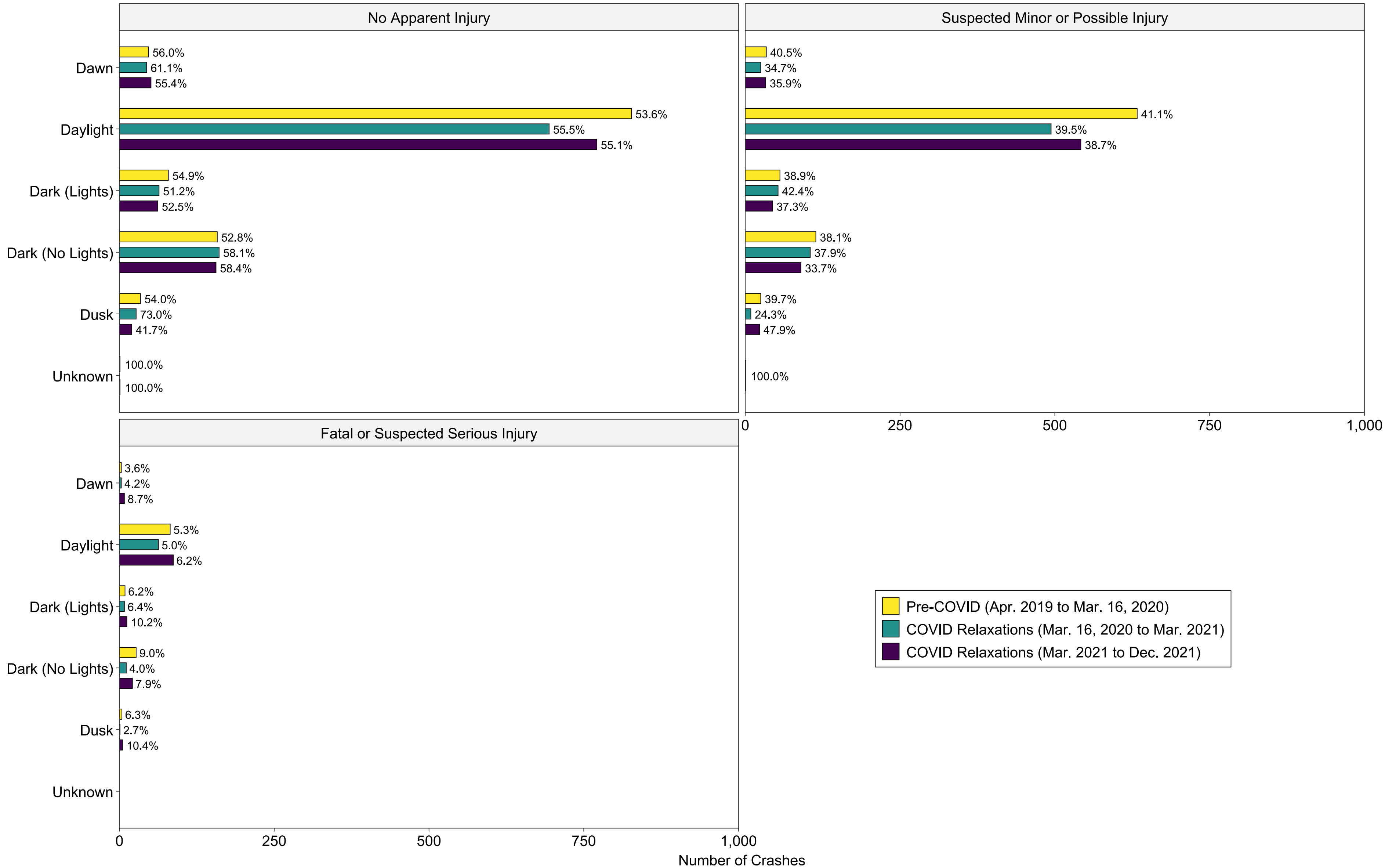

Figure 4.12: Frequency and Proportion of Truck-Involved Crashes by Lighting Condition, Time Period, and Highest Sustained Injury Severity

Table 4.11: Test for Equality of Proportions of Truck-Involved Crashes by Lighting Condition and Time Period

Lighting Condition	Pre-COVID (Apr. 2019 - Mar. 16, 2020)		COVID Relaxations (Low VMT) (Mar. 16, 2020 - Mar. 2021)		COVID Relaxations (Normal VMT) (Mar. 2021 - Dec. 2021)		*p*-value[1]	*p*-value[2]	*p*-value[3]
	Frequency	Proportion of Total	Frequency	Proportion of Total	Frequency	Proportion of Total			
Dawn	84	3.9%	72	4.1%	92	4.8%	0.817	0.190	0.308
Daylight	1,542	72.3%	1,251	71.0%	1,400	72.7%	0.358	0.777	0.243
Dark (Lights)	144	6.8%	125	7.1%	118	6.1%	0.678	0.419	0.239
Dark (No Lights)	299	14.0%	277	15.7%	267	13.9%	0.138	0.887	0.114
Dusk	63	3.0%	37	2.1%	48	2.5%	0.093	0.368	0.426
Unknown	1	0.0%	1	0.1%	1	0.1%	0.893	0.942	0.950
Total	2,133	100%	1,763	100%	1,926	100%			

[1] Comparison between Pre-COVID (Apr. 2019 - Mar. 16, 2020) and COVID Relaxations (Mar. 16, 2020 - Mar. 2021)

[2] Comparison between Pre-COVID (Apr. 2019 - Mar. 16, 2020) and COVID Relaxations (Mar. 2021 - Dec. 2021)

[3] Comparison between COVID Relaxations (Mar. 16, 2020 - Mar. 2021) and COVID Relaxations (Mar. 2021 - Dec. 2021)

[a] Significant with at least 95% confidence

Table 4.12: Test for Equality of Proportions of Fatal and Suspected Serious Injury Truck-Involved Crashes by Lighting Condition and Time Period

Lighting Condition	Pre-COVID (Apr. 2019 - Mar. 16, 2020)		COVID Relaxations (Low VMT) (Mar. 16, 2020 - Mar. 2021)		COVID Relaxations (Normal VMT) (Mar. 2021 - Dec. 2021)		*p*-value[1]	*p*-value[2]	*p*-value[3]
	Frequency	Proportion of Total	Frequency	Proportion of Total	Frequency	Proportion of Total			
Dawn	3	0.1%	3	0.2%	8	0.4%	0.815	0.093	0.172
Daylight	82	3.8%	63	3.6%	87	4.5%	0.657	0.284	0.147
Dark (Lights)	9	0.4%	8	0.5%	12	0.6%	0.881	0.372	0.484
Dark (No Lights)	27	1.3%	11	0.6%	21	1.1%	**0.042**[a]	0.606	0.127
Dusk	4	0.2%	1	0.1%	5	0.3%	0.256	0.626	0.127
Total	125	0	86	0	133	0			

[1] Comparison between Pre-COVID (Apr. 2019 - Mar. 16, 2020) and COVID Relaxations (Mar. 16, 2020 - Mar. 2021)

[2] Comparison between Pre-COVID (Apr. 2019 - Mar. 16, 2020) and COVID Relaxations (Mar. 2021 - Dec. 2021)

[3] Comparison between COVID Relaxations (Mar. 16, 2020 - Mar. 2021) and COVID Relaxations (Mar. 2021 - Dec. 2021)

[a] Significant with at least 95% confidence

4.1.7 Older Drivers

Figure 4.13 shows the proportion and frequency of truck-involved crashes by older truck drivers and time period and Figure 4.14 shows the proportion and frequency of truck-involved crashes by older truck drivers, time period, and highest sustained injury severity. Table 4.13 and Table 4.14 present the results of the z-tests of proportions, respectively.[6]

There were no significant differences in proportions when considering all crashes. There was a difference in proportions that met a lower significance threshold (90%). Specifically, the proportion of crashes that involved drivers 65 years of age or greater was lower in the normal VMT COVID relaxations period compared to the low VMT COVID relaxations period.

Considering only fatal and suspected serious injury crashes, the proportion of crashes involving drivers less than 65 years of age was higher in the normal VMT COVID relaxations period compared to the pre-COVID period. In addition, the proportion of crashes involving drivers 65 years of age or greater was higher in the normal VMT COVID relaxations period compared to the low VMT COVID relaxations period.

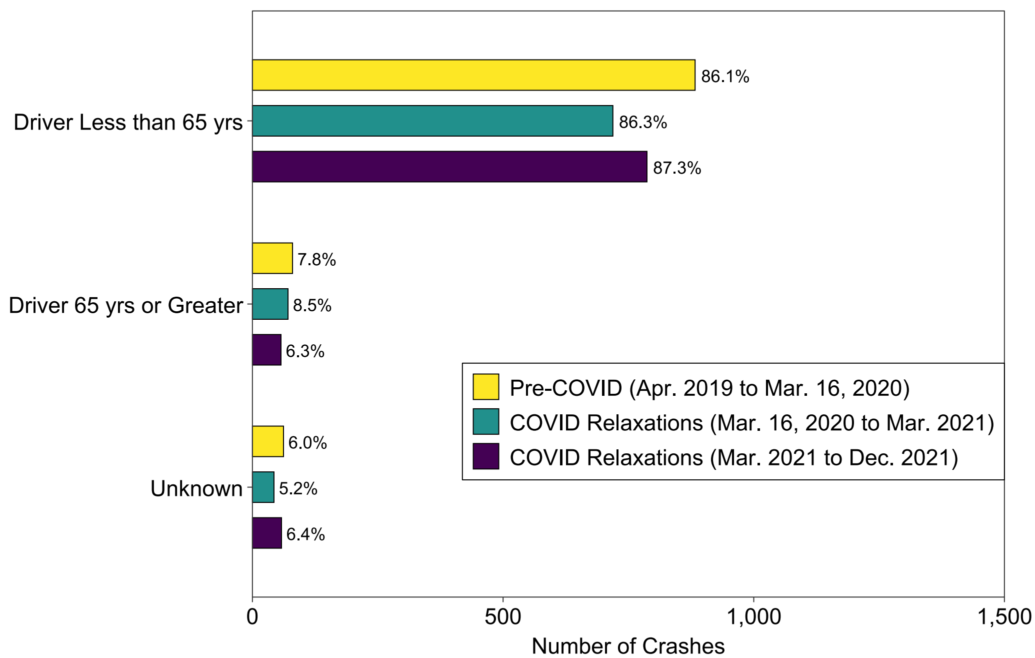

Figure 4.13: Frequency and Proportion of Truck-Involved Crashes of Older Truck Drivers by Time Period

[6] Older truck drivers are defined as drivers 65 years or older. This is based on Oregon's Transportation Safety Action Plan.

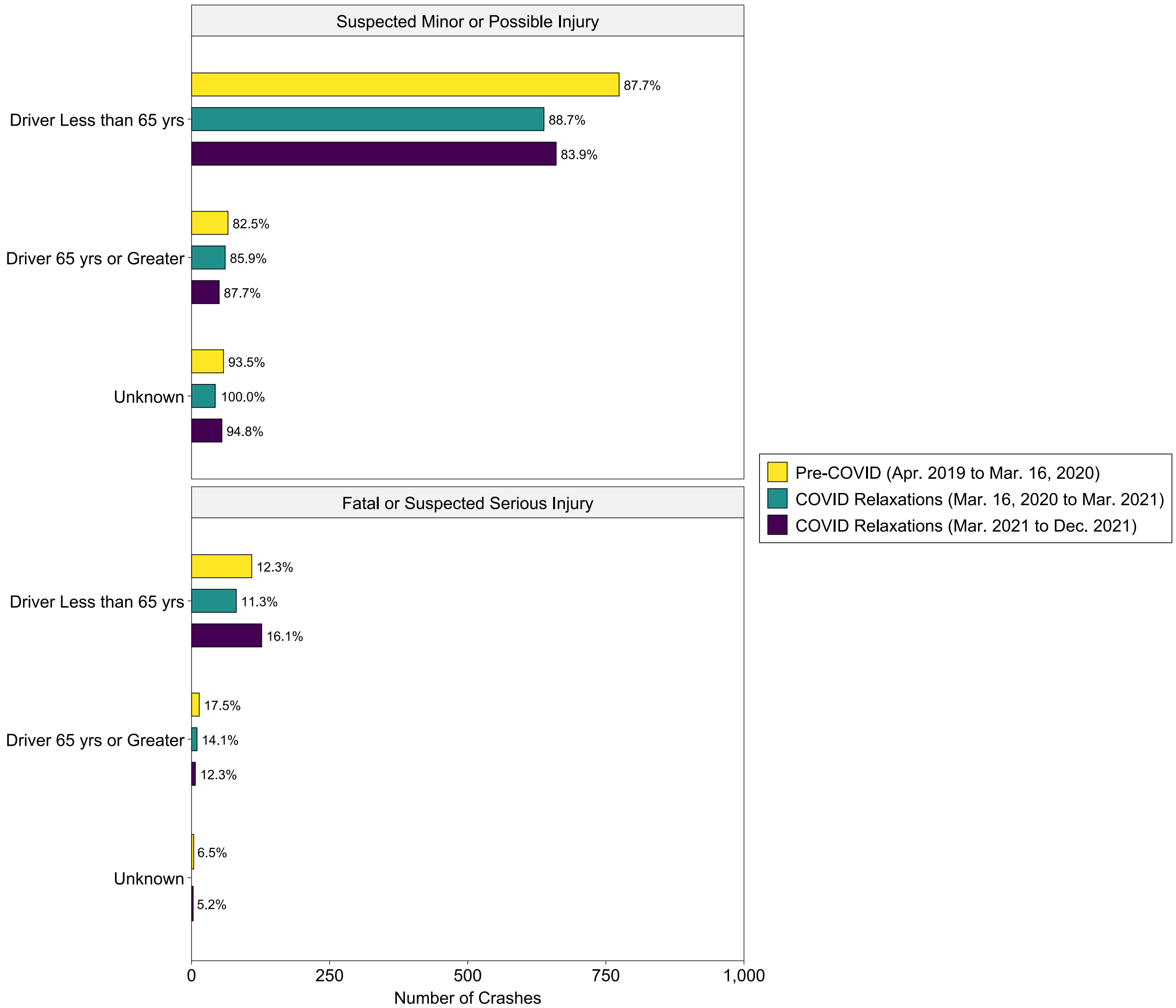

Figure 4.14: Frequency and Proportion of Truck-Involved Crashes of Older Truck Drivers by Time Period and Highest Sustained Injury Severity

Table 4.13: Test for Equality of Proportions of Truck-Involved Crashes by Older Truck Drivers and Time Period

Age	Pre-COVID (Apr. 2019 - Mar. 16, 2020)		COVID Relaxations (Low VMT) (Mar. 16, 2020 - Mar. 2021)		COVID Relaxations (Normal VMT) (Mar. 2021 - Dec. 2021)		*p*-value[1]	*p*-value[2]	*p*-value[3]
	Frequency	Proportion of Total	Frequency	Proportion of Total	Frequency	Proportion of Total			
Driver Less than 65 yrs	883	39.8%	719	38.6%	787	39.1%	0.440	0.660	0.739
Driver 65 yrs or Greater	80	3.6%	71	3.8%	57	2.8%	0.727	0.157	0.089
Unknown	1,258	56.6%	1,074	57.6%	1,169	58.1%	0.530	0.347	0.775
Total	2,221	100%	1,864	100%	2,013	100%			

[1] Comparison between Pre-COVID (Apr. 2019 - Mar. 16, 2020) and COVID Relaxations (Mar. 16, 2020 - Mar. 2021)
[2] Comparison between Pre-COVID (Apr. 2019 - Mar. 16, 2020) and COVID Relaxations (Mar. 2021 - Dec. 2021)
[3] Comparison between COVID Relaxations (Mar. 16, 2020 - Mar. 2021) and COVID Relaxations (Mar. 2021 - Dec. 2021)
[a] Significant with at least 95% confidence

Table 4.14: Test for Equality of Proportions of Fatal and Suspected Serious Injury Truck-Involved Crashes by Older Truck Drivers and Time Period

Age	Pre-COVID (Apr. 2019 - Mar. 16, 2020)		COVID Relaxations (Low VMT) (Mar. 16, 2020 - Mar. 2021)		COVID Relaxations (Normal VMT) (Mar. 2021 - Dec. 2021)		*p*-value[1]	*p*-value[2]	*p*-value[3]
	Frequency	Proportion of Total	Frequency	Proportion of Total	Frequency	Proportion of Total			
Driver Less than 65 yrs	109	4.9%	81	4.3%	127	6.3%	0.395	**0.047**[a]	**0.007**[a]
Driver 65 yrs or Greater	14	0.6%	10	0.5%	7	0.3%	0.696	0.191	0.374
Unknown	4	0.2%	0	0.0%	3	0.1%	0.067	0.804	0.095
Total	127	6%	91	5%	137	7%			

[1] Comparison between Pre-COVID (Apr. 2019 - Mar. 16, 2020) and COVID Relaxations (Mar. 16, 2020 - Mar. 2021)
[2] Comparison between Pre-COVID (Apr. 2019 - Mar. 16, 2020) and COVID Relaxations (Mar. 2021 - Dec. 2021)
[3] Comparison between COVID Relaxations (Mar. 16, 2020 - Mar. 2021) and COVID Relaxations (Mar. 2021 - Dec. 2021)
[a] Significant with at least 95% confidence

4.1.8 Driver Residence

Figure 4.15 shows the proportion and frequency of truck-involved crashes by truck driver residence and time period and Figure 4.16 shows the proportion and frequency of truck-involved crashes and truck driver residence, time period, and highest sustained injury severity. Table 4.15 and Table 4.16 present the results of the z-tests of proportions, respectively.

There were no significant differences in proportions when considering all crashes. However, there was a difference in proportions that met a lower significance threshold (90%). There was a lower proportion of non-Oregon-resident drivers involved in the normal VMT COVID relaxations period compared to the low VMT COVID relaxations period.

Considering only fatal and suspected serious injury crashes, there was a significantly higher proportion of Oregon residents (within 25 miles of home) in the normal VMT COVID relaxations period compared to the pre-COVID period. There was also a significantly higher proportion of Oregon residents (within 25 miles of home) in the normal VMT COVID relaxations period compared to the low VMT COVID relaxations period.

At a lower significance threshold (90%), there was a lower proportion of crashes involving non-residents in the low VMT COVID relaxations period compared to the pre-COVID period.

Note the large number of unknown if Oregon resident observations in Figure 4.15 and Table 4.15Table 4.1; this is due to driver residence being coded as unknown if Oregon resident for any no injury crash.

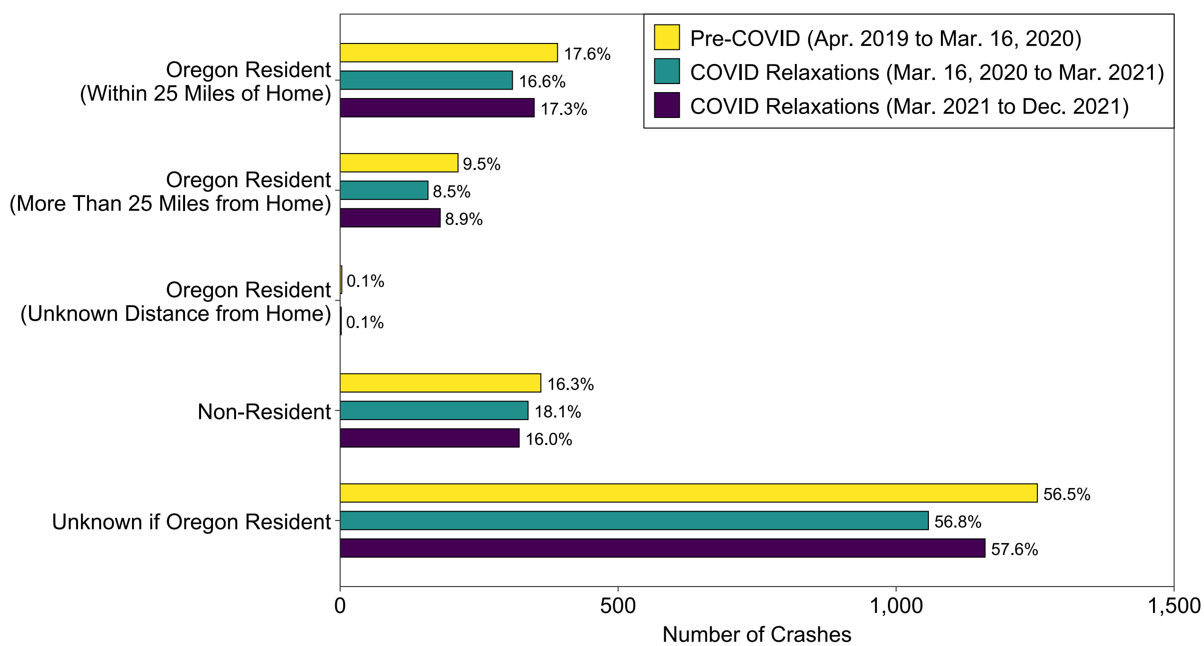

Figure 4.15: Frequency and Proportions of Truck-Involved Crashes by Truck Driver Residency and Time Period

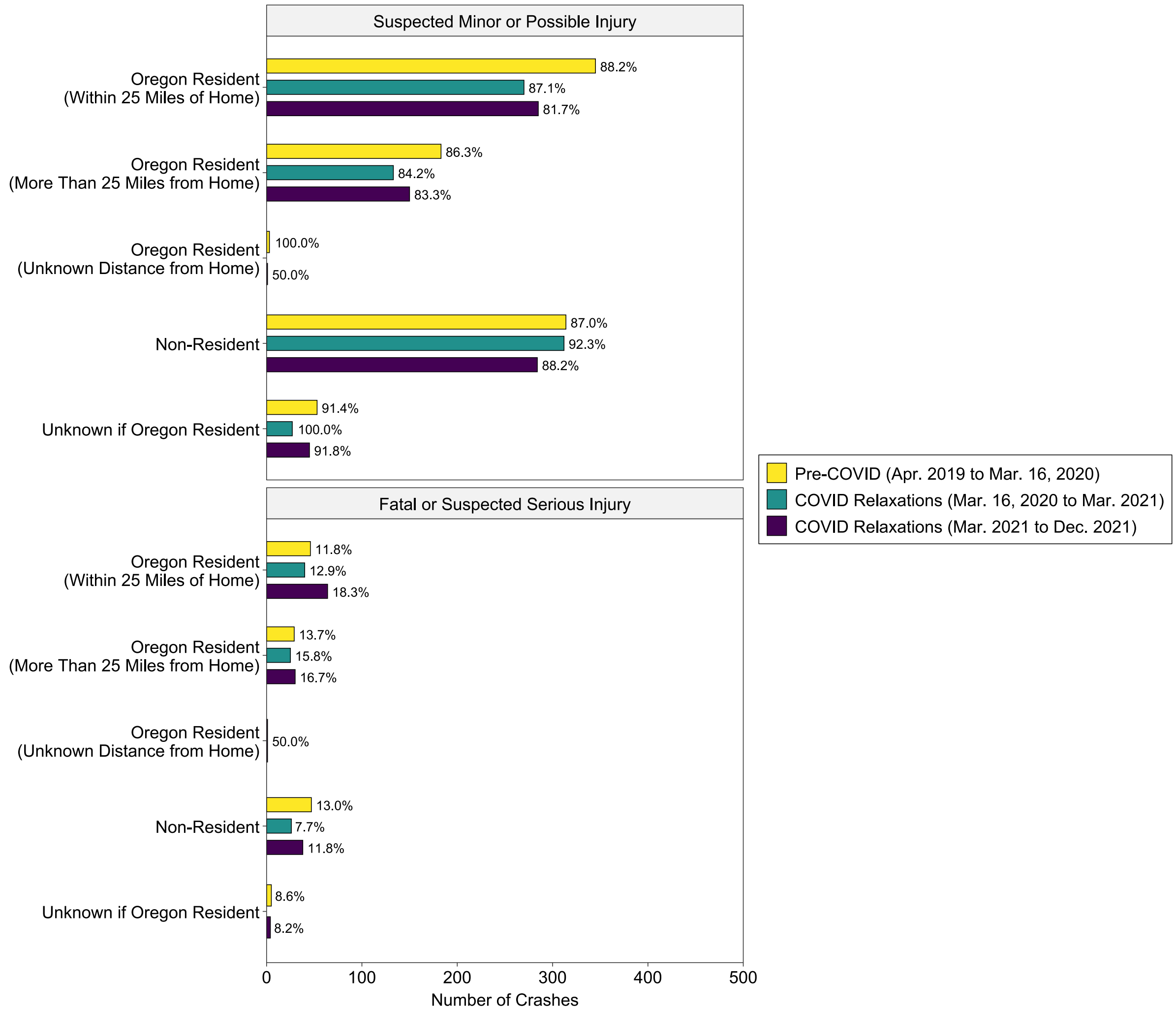

Figure 4.16: Frequency and Proportion of Truck-Involved Crashes by Truck Driver Residency, Time Period, and Highest Sustained Injury Severity

Table 4.15: Test for Equality of Proportions of Truck-Involved Crashes by Truck Driver Residence and Time Period

Driver Residence	Pre-COVID (Apr. 2019 - Mar. 16, 2020)		COVID Relaxations (Low VMT) (Mar. 16, 2020 - Mar. 2021)		COVID Relaxations (Normal VMT) (Mar. 2021 - Dec. 2021)		*p*-value[1]	*p*-value[2]	*p*-value[3]
	Frequency	Proportion of Total	Frequency	Proportion of Total	Frequency	Proportion of Total			
Oregon Resident (Within 25 Miles of Home)	391	17.6%	310	16.6%	349	17.3%	0.411	0.819	0.558
Oregon Resident (More Than 25 Miles from Home)	212	9.5%	158	8.5%	180	8.9%	0.236	0.499	0.608
Oregon Resident (Unknown Distance from Home)	3	0.1%	0	0.0%	2	0.1%	0.112	0.735	0.173
Non-Resident	361	16.3%	338	18.1%	322	16.0%	0.112	0.820	0.077
Unknown if Oregon Resident	1,254	56.5%	1,058	56.8%	1,160	57.6%	0.848	0.445	0.586
Total	2,221	100%	1,864	100%	2,013	100%			

[1] Comparison between Pre-COVID (Apr. 2019 - Mar. 16, 2020) and COVID Relaxations (Mar. 16, 2020 - Mar. 2021)

[2] Comparison between Pre-COVID (Apr. 2019 - Mar. 16, 2020) and COVID Relaxations (Mar. 2021 - Dec. 2021)

[3] Comparison between COVID Relaxations (Mar. 16, 2020 - Mar. 2021) and COVID Relaxations (Mar. 2021 - Dec. 2021)

[a] Significant with at least 95% confidence

Table 4.16: Test for Equality of Proportions of Fatal and Suspected Serious Injury Truck-Involved Crashes by Truck Driver Residence and Time Period

Driver Residence	Pre-COVID (Apr. 2019 - Mar. 16, 2020)		COVID Relaxations (Low VMT) (Mar. 16, 2020 - Mar. 2021)		COVID Relaxations (Normal VMT) (Mar. 2021 - Dec. 2021)		*p*-value[1]	*p*-value[2]	*p*-value[3]
	Frequency	Proportion of Total	Frequency	Proportion of Total	Frequency	Proportion of Total			
Oregon Resident (Within 25 Miles of Home)	46	2.1%	40	2.1%	64	3.2%	0.868	**0.024**[a]	**0.047**[a]
Oregon Resident (More Than 25 Miles from Home)	29	1.3%	25	1.3%	30	1.5%	0.921	0.609	0.695
Oregon Resident (Unknown Distance from Home)	0	0.0%	0	0.0%	1	0.0%	NA	0.293	0.336
Non-Resident	47	2.1%	26	1.4%	38	1.9%	0.083	0.597	0.229
Unknown if Oregon Resident	5	0.2%	0	0.0%	4	0.2%	**0.040**[a]	0.852	0.054
Total	127	6%	91	5%	137	7%			

[1] Comparison between Pre-COVID (Apr. 2019 - Mar. 16, 2020) and COVID Relaxations (Mar. 16, 2020 - Mar. 2021)
[2] Comparison between Pre-COVID (Apr. 2019 - Mar. 16, 2020) and COVID Relaxations (Mar. 2021 - Dec. 2021)
[3] Comparison between COVID Relaxations (Mar. 16, 2020 - Mar. 2021) and COVID Relaxations (Mar. 2021 - Dec. 2021)
[a] Significant with at least 95% confidence

[1] Comparison between Pre-COVID (Apr. 2019 - Mar. 16, 2020) and COVID Relaxations (Mar. 16, 2020 - Mar. 2021)
[2] Comparison between Pre-COVID (Apr. 2019 - Mar. 16, 2020) and COVID Relaxations (Mar. 2021 - Dec. 2021)
[3] Comparison between COVID Relaxations (Mar. 16, 2020 - Mar. 2021) and COVID Relaxations (Mar. 2021 - Dec. 2021)
[a] Significant with at least 95% confidence

4.1.9 Road Surface Condition

Figure 4.17 shows the proportion and frequency of truck-involved crashes by road surface condition and time period and Figure 4.18 shows the proportion and frequency of truck-involved crashes by road surface condition, time period, and highest sustained injury severity. Table 4.17 and Table 4.18 present the results of the z-tests of proportions, respectively.

Considering all crashes, there were significant differences in proportions for dry, ice, and snow surface conditions. For dry surface conditions, there was a significantly lower proportion of crashes in the low VMT COVID relaxations period compared to the pre-COVID period and a significantly lower proportion in the low VMT COVID relaxations period compared to the normal VMT COVID relaxations period. At a lower significance threshold (90%), there was also a lower proportion in the normal VMT COVID relaxations period compared to the pre-COVID period.

For icy surface conditions, the opposite was observed; that is, there was a significantly higher proportion of crashes in the low VMT COVID relaxations period compared to the pre-COVID period and a significantly higher proportion in the low VMT COVID relaxations period compared to the normal VMT COVID relaxations period. At a lower significance threshold (90%), there was a lower proportion in the normal VMT COVID relaxations period compared to the pre-COVID period.

For snowy surface conditions, the same trend was observed; there was a significantly higher proportion of crashes in the low VMT COVID relaxations period compared to the pre-COVID period and a significantly higher proportion in the low VMT COVID relaxations period compared to the normal VMT COVID relaxations period.

Considering only fatal and suspected serious injury crashes, there was a significantly lower proportion of crashes that occurred on dry surface conditions in the low VMT COVID relaxations period compared to the pre-COVID, as well as a significantly lower proportion of crashes that occurred on dry surface conditions compared to the normal VMT COVID relaxations period.

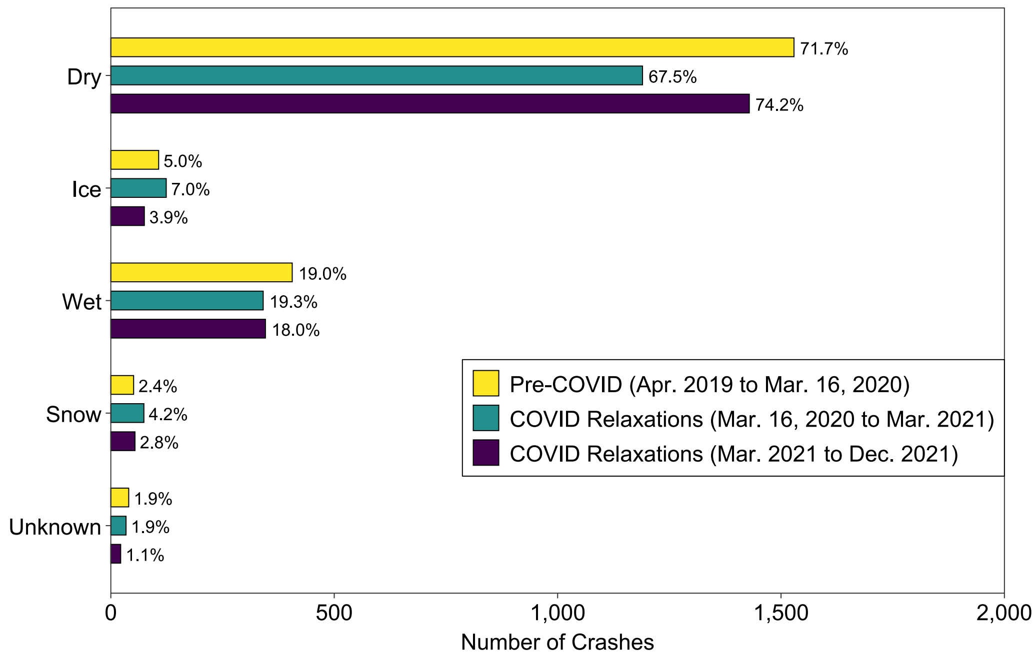

Figure 4.17: Frequency and Proportion of Truck-Involved Crashes by Road Surface Condition and Time Period

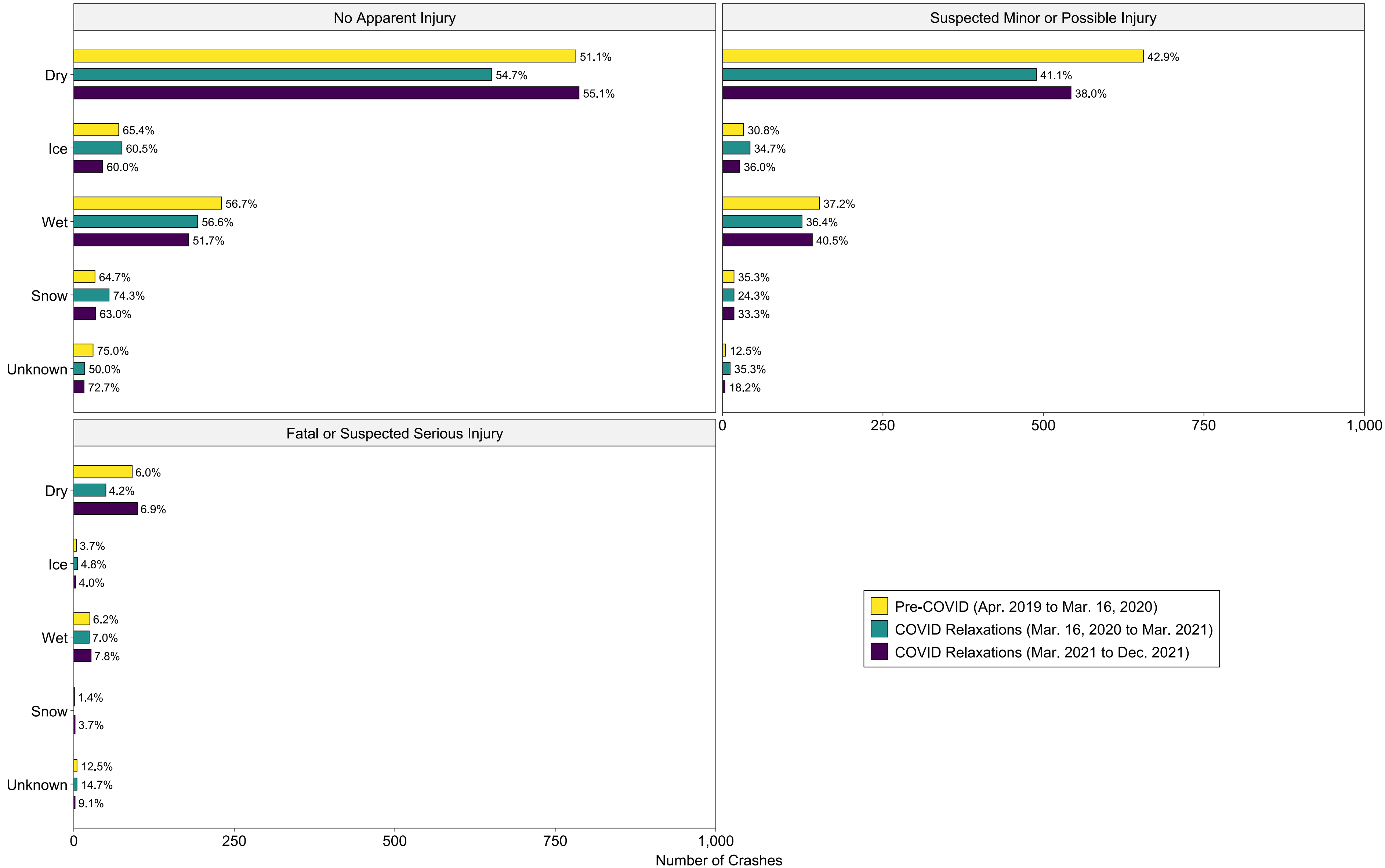

Figure 4.18: Frequency and Proportion of Truck-Involved Crashes by Road Surface Condition, Time Period, and Highest Sustained Injury Severity

Table 4.17: Test for Equality of Proportions of Truck-Involved Crashes by Road Surface Condition and Time Period

Road Surface Condition	Pre-COVID (Apr. 2019 - Mar. 16, 2020)		COVID Relaxations (Low VMT) (Mar. 16, 2020 - Mar. 2021)		COVID Relaxations (Normal VMT) (Mar. 2021 - Dec. 2021)		*p*-value[1]	*p*-value[2]	*p*-value[3]
	Frequency	Proportion of Total	Frequency	Proportion of Total	Frequency	Proportion of Total			
Dry	1,529	71.7%	1,190	67.5%	1,429	74.2%	**0.005**[a]	0.072	**0.000**[a]
Ice	107	5.0%	124	7.0%	75	3.9%	**0.008**[a]	0.084	**0.000**[a]
Wet	406	19.0%	341	19.3%	346	18.0%	0.808	0.381	0.283
Snow	51	2.4%	74	4.2%	54	2.8%	**0.001**[a]	0.408	**0.021**[a]
Unknown	40	1.9%	34	1.9%	22	1.1%	0.904	0.057	0.051
Total	2,133	100%	1,763	100%	1,926	100%			

[1] Comparison between Pre-COVID (Apr. 2019 - Mar. 16, 2020) and COVID Relaxations (Mar. 16, 2020 - Mar. 2021)
[2] Comparison between Pre-COVID (Apr. 2019 - Mar. 16, 2020) and COVID Relaxations (Mar. 2021 - Dec. 2021)
[3] Comparison between COVID Relaxations (Mar. 16, 2020 - Mar. 2021) and COVID Relaxations (Mar. 2021 - Dec. 2021)
[a] Significant with at least 95% confidence

Table 4.18: Test for Equality of Proportions of Fatal and Suspected Serious Injury Truck-Involved Crashes by Road Surface Condition and Time Period

Road Surface Condition	Pre-COVID (Apr. 2019 - Mar. 16, 2020)		COVID Relaxations (Low VMT) (Mar. 16, 2020 - Mar. 2021)		COVID Relaxations (Normal VMT) (Mar. 2021 - Dec. 2021)		*p*-value[1]	*p*-value[2]	*p*-value[3]
	Frequency	Proportion of Total	Frequency	Proportion of Total	Frequency	Proportion of Total			
Dry	91	4.3%	50	2.8%	99	5.1%	**0.017**[a]	0.188	**0.000**[a]
Ice	4	0.2%	6	0.3%	3	0.2%	0.348	0.808	0.256
Wet	25	1.2%	24	1.4%	27	1.4%	0.598	0.516	0.916
Snow	0	0.0%	1	0.1%	2	0.1%	0.271	0.137	0.616
Unknown	5	0.2%	5	0.3%	2	0.1%	0.763	0.317	0.210
Total	125	6%	86	5%	133	7%			

[1] Comparison between Pre-COVID (Apr. 2019 - Mar. 16, 2020) and COVID Relaxations (Mar. 16, 2020 - Mar. 2021)
[2] Comparison between Pre-COVID (Apr. 2019 - Mar. 16, 2020) and COVID Relaxations (Mar. 2021 - Dec. 2021)
[3] Comparison between COVID Relaxations (Mar. 16, 2020 - Mar. 2021) and COVID Relaxations (Mar. 2021 - Dec. 2021)
[a] Significant with at least 95% confidence

4.1.10 Time-of-Day

Figure 4.19 shows the proportion and frequency of truck-involved crashes by time-of-day and time period and Figure 4.20 shows the proportion and frequency of truck-involved crashes by time-of-day, time period, and highest sustained injury severity. Table 4.19 and Table 4.20 present the results of the z-tests of proportions, respectively.

Considering all crashes, there was a significantly higher proportion of crashes that occurred from 12 a.m. to 3 a.m. in the low VMT COVID relaxations period compared to the pre-COVID period. Additionally, there was a significantly higher proportion of crashes that occurred from 12 a.m. to 3 a.m. in the normal VMT COVID relaxations period compared to the pre-COVID period.

Considering only fatal and suspected serious injury crashes, there was a significantly higher proportion of crashes that occurred from 12 a.m. to 3 a.m. in the normal VMT COVID relaxations period compared to the low VMT COVID relaxations period. At a lower significance threshold (90%), there was a lower proportion of crashes that occurred from 12 a.m. to 3 p.m. in the low VMT COVID relaxations period compared to the pre-COVID period.

Other differences that met a lower significance threshold (90%) when considering fatal and suspected injury crashes include 9 a.m. to 12 p.m. (higher proportion in the low VMT COVID relaxations period compared to the pre-COVID period), 12 p.m. to 3 p.m. (higher proportion in the normal VMT COVID relaxations period compared to the low VMT COVID relaxations period), and 6 p.m. to 9 p.m. (lower proportion in the low VMT COVID relaxations period compared to the pre-COVID period and the normal VMT COVID relaxations period).

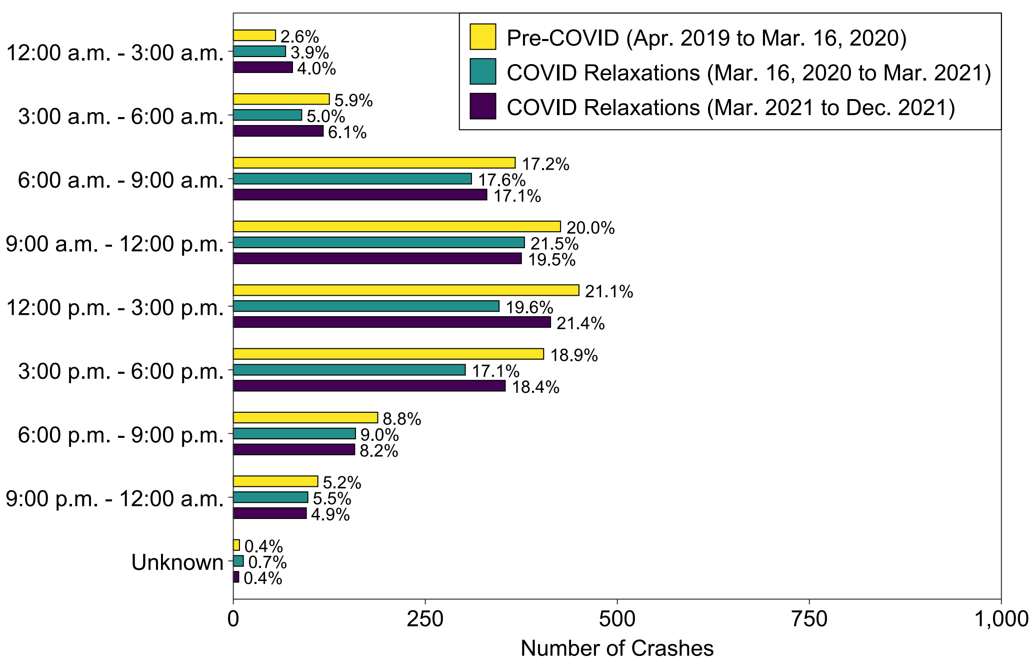

Figure 4.19: Frequency and Proportion of Truck-Involved Crashes by Time-of-Day and Time Period

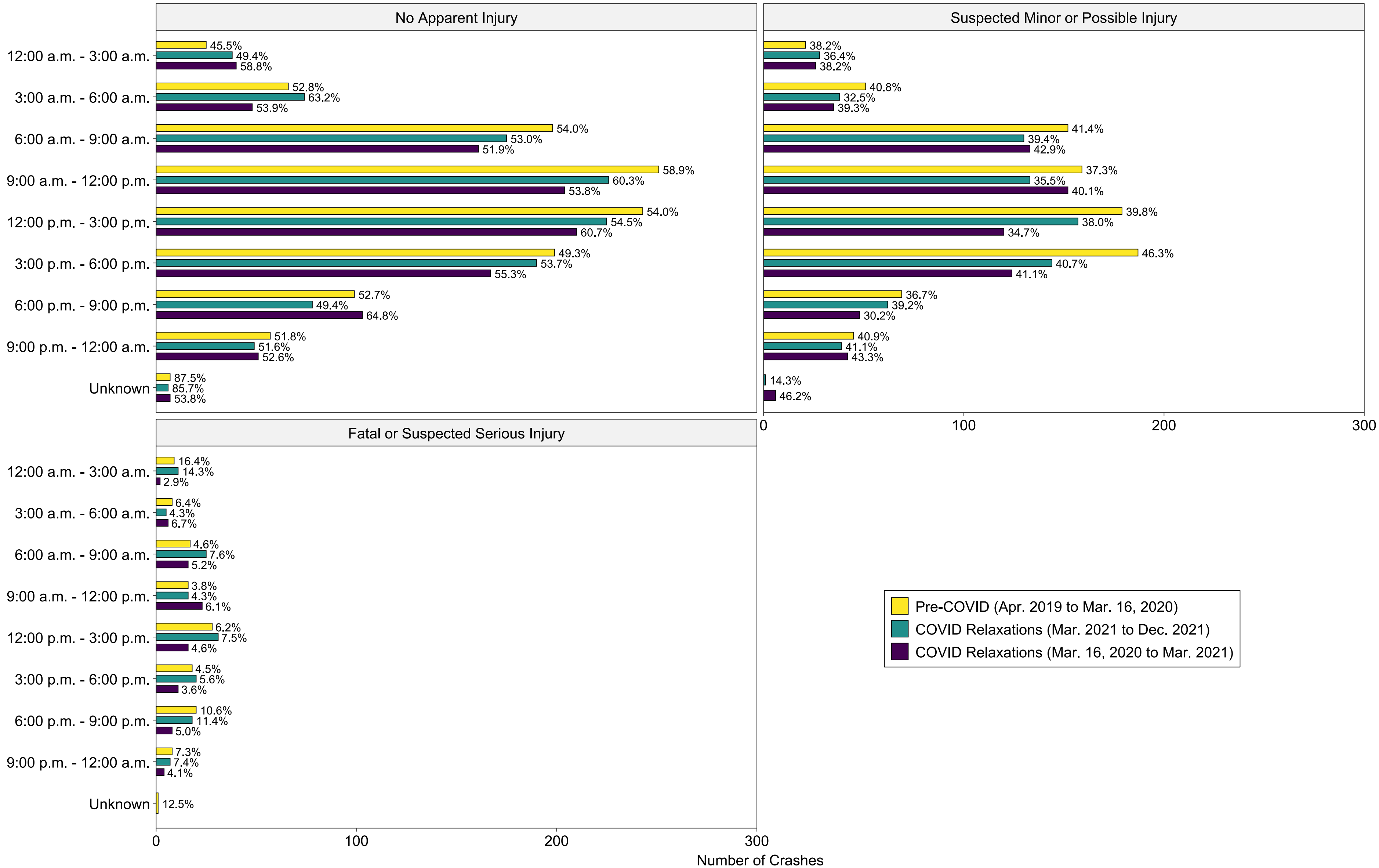

Figure 4.20: Frequency and Proportion of Truck-Involved Crashes by Time-of-Day, Time Period, and Highest Sustained Injury Severity

Table 4.19: Test for Equality of Proportions of Truck-Involved Crashes by Time-of-Day and Time Period

Time-of-Day	Pre-COVID (Apr. 2019 - Mar. 16, 2020)		COVID Relaxations (Low VMT) (Mar. 16, 2020 - Mar. 2021)		COVID Relaxations (Normal VMT) (Mar. 2021 - Dec. 2021)		*p*-value[1]	*p*-value[2]	*p*-value[3]
	Frequency	Proportion of Total	Frequency	Proportion of Total	Frequency	Proportion of Total			
12:00 a.m. - 3:00 a.m.	55	2.58%	68	3.86%	77	4.00%	**0.023**[a]	**0.011**[a]	0.826
3:00 a.m. - 6:00 a.m.	125	5.86%	89	5.05%	117	6.07%	0.268	0.773	0.175
6:00 a.m. - 9:00 a.m.	367	17.21%	310	17.58%	330	17.13%	0.757	0.952	0.719
9:00 a.m. - 12:00 p.m.	426	19.97%	379	21.50%	375	19.47%	0.242	0.689	0.127
12:00 p.m. - 3:00 p.m.	450	21.10%	346	19.63%	413	21.44%	0.257	0.788	0.172
3:00 p.m. - 6:00 p.m.	404	18.94%	302	17.13%	354	18.38%	0.144	0.647	0.321
6:00 p.m. - 9:00 p.m.	188	8.81%	159	9.02%	158	8.20%	0.823	0.487	0.378
9:00 p.m. - 12:00 a.m.	110	5.16%	97	5.50%	95	4.93%	0.633	0.744	0.437
Unknown	8	0.38%	13	0.74%	7	0.36%	0.124	0.951	0.122
Total	2,133	100%	1,763	100%	1,926	100%			

[1] Comparison between Pre-COVID (Apr. 2019 - Mar. 16, 2020) and COVID Relaxations (Mar. 16, 2020 - Mar. 2021)

[2] Comparison between Pre-COVID (Apr. 2019 - Mar. 16, 2020) and COVID Relaxations (Mar. 2021 - Dec. 2021)

[3] Comparison between COVID Relaxations (Mar. 16, 2020 - Mar. 2021) and COVID Relaxations (Mar. 2021 - Dec. 2021)

[a] Significant with at least 95% confidence

Table 4.20: Test for Equality of Proportions of Fatal and Suspected Injury Truck-Involved Crashes by Time-of-Day and Time Period

Time-of-Day	Pre-COVID (Apr. 2019 - Mar. 16, 2020)		COVID Relaxations (Low VMT) (Mar. 16, 2020 - Mar. 2021)		COVID Relaxations (Normal VMT) (Mar. 2021 - Dec. 2021)		*p*-value[1]	*p*-value[2]	*p*-value[3]
	Frequency	Proportion of Total	Frequency	Proportion of Total	Frequency	Proportion of Total			
12:00 a.m. - 3:00 a.m.	9	0.42%	2	0.11%	11	0.57%	0.071	0.498	**0.019**[a]
3:00 a.m. - 6:00 a.m.	8	0.38%	6	0.34%	5	0.26%	0.857	0.516	0.653
6:00 a.m. - 9:00 a.m.	17	0.80%	16	0.91%	25	1.30%	0.708	0.115	0.258
9:00 a.m. - 12:00 p.m.	16	0.75%	23	1.30%	16	0.83%	0.084	0.772	0.160
12:00 p.m. - 3:00 p.m.	28	1.31%	16	0.91%	31	1.61%	0.234	0.430	0.058
3:00 p.m. - 6:00 p.m.	18	0.84%	11	0.62%	20	1.04%	0.427	0.520	0.168
6:00 p.m. - 9:00 p.m.	20	0.94%	8	0.45%	18	0.93%	0.075	0.992	0.081
9:00 p.m. - 12:00 a.m.	8	0.38%	4	0.23%	7	0.36%	0.406	0.951	0.447
Unknown	1	0.05%	0	0.00%	0	0.00%	0.363	0.342	---
Total	125		86		133				

[1] Comparison between Pre-COVID (Apr. 2019 - Mar. 16, 2020) and COVID Relaxations (Mar. 16, 2020 - Mar. 2021)
[2] Comparison between Pre-COVID (Apr. 2019 - Mar. 16, 2020) and COVID Relaxations (Mar. 2021 - Dec. 2021)
[3] Comparison between COVID Relaxations (Mar. 16, 2020 - Mar. 2021) and COVID Relaxations (Mar. 2021 - Dec. 2021)
[a] Significant with at least 95% confidence

4.1.11 Vehicles Involved

Figure 4.21 shows the proportion and frequency of truck-involved crashes by the number of vehicles involved and time period and Figure 4.22 shows the proportion and frequency of truck-involved crashes by the number of vehicles involved, time period, and highest sustained injury severity. Table 4.21 and Table 4.22 present the results of the z-tests of proportions, respectively.

Considering all crashes, there was a significantly higher proportion of single vehicle crashes in the low VMT COVID relaxations period compared to the pre-COVID, as well as a significantly higher proportion compared to the normal VMT COVID relaxations period. Conversely, there was a significantly lower proportion of multi-vehicle crashes in the low VMT COVID relaxations period compared to the pre-COVID period and to the normal VMT COVID relaxations period.

Considering only fatal and suspected serious injury crashes, the proportion of multi-vehicle crashes in the normal VMT COVID relaxations period was significantly higher compared to the low VMT COVID relaxations period.

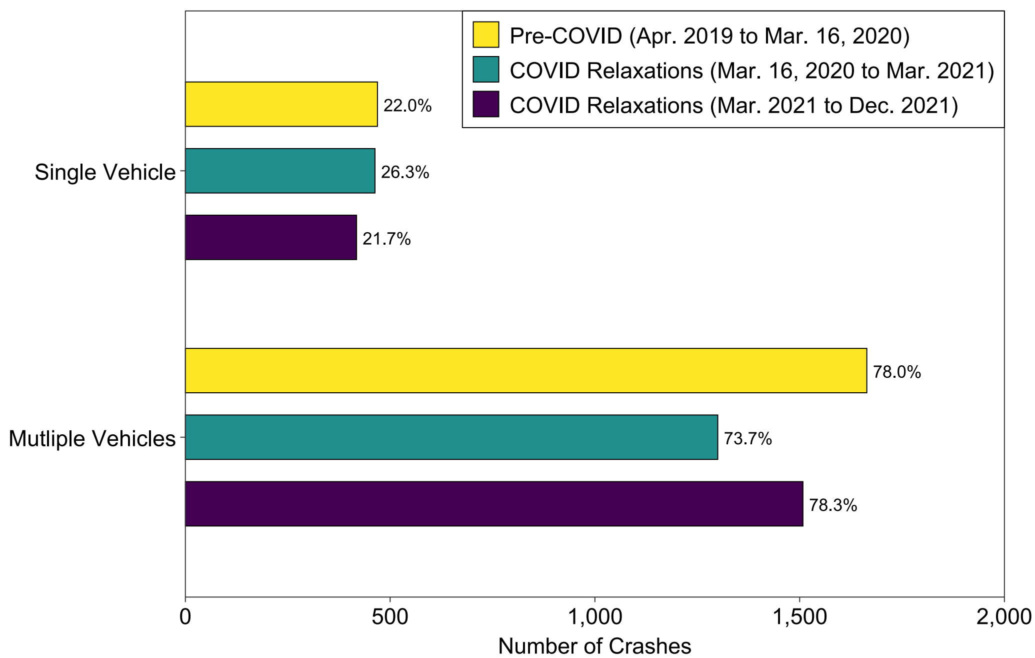

Figure 4.21: Frequency and Proportion of Truck-Involved Crashes by Number of Vehicles Involved and Time Period

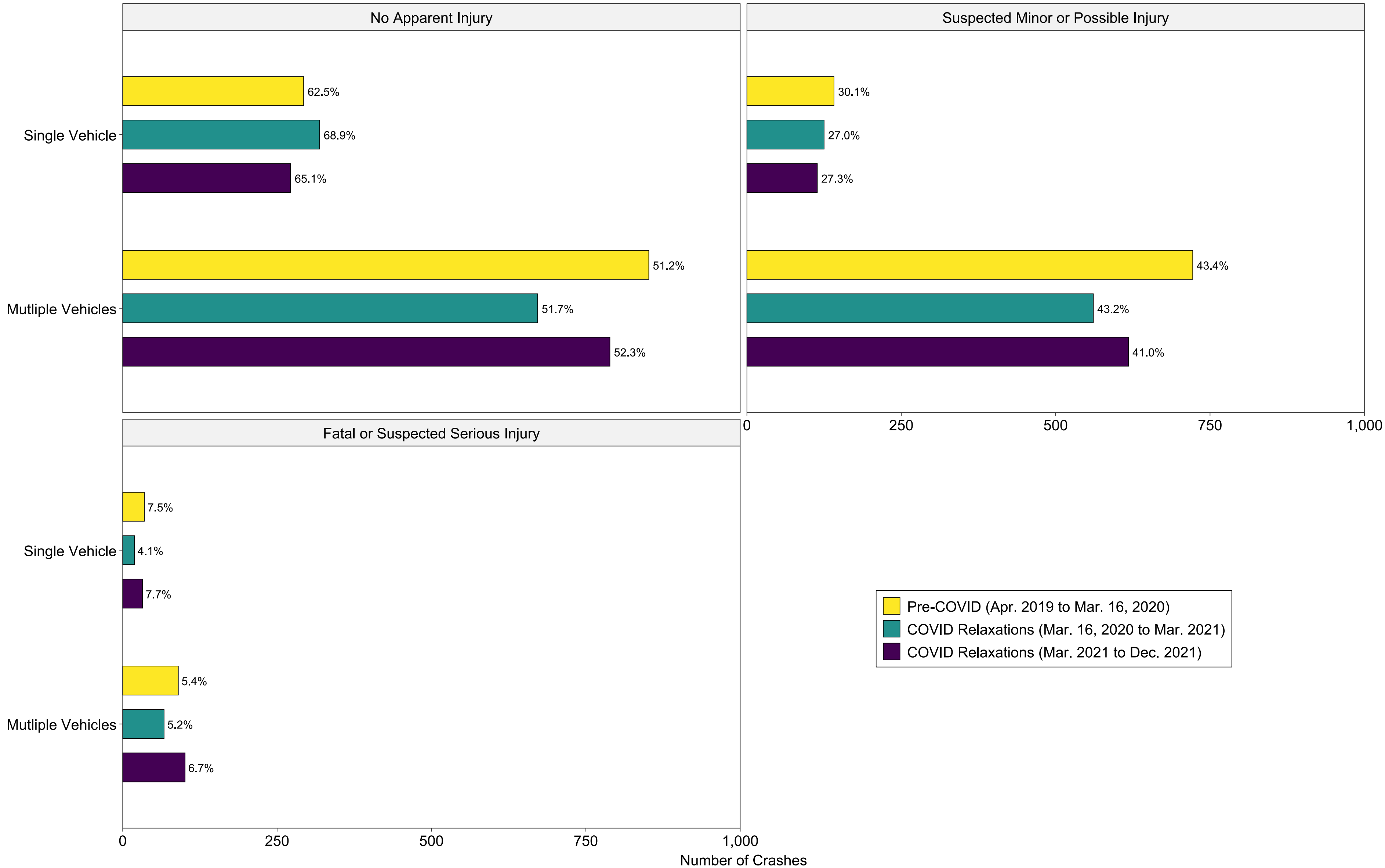

Figure 4.22: Frequency and Proportion of Truck-Involved Crashes by Number of Vehicles Involved, Time Period, and Highest Sustained Injury Severity

Table 4.21: Test for Equality of Proportions of Truck-Involved Crashes by Number of Vehicles and Time Period

Number of Vehicles	Pre-COVID (Apr. 2019 - Mar. 16, 2020)		COVID Relaxations (Low VMT) (Mar. 16, 2020 - Mar. 2021)		COVID Relaxations (Normal VMT) (Mar. 2021 - Dec. 2021)		*p*-value[1]	*p*-value[2]	*p*-value[3]
	Frequency	Proportion of Total	Frequency	Proportion of Total	Frequency	Proportion of Total			
Single Vehicle	469	21.99%	463	26.26%	418	21.70%	**0.002**[a]	0.826	**0.001**[a]
Multiple Vehicles	1,664	78.01%	1,300	73.74%	1,508	78.30%	**0.002**[a]	0.826	**0.001**[a]
Total	2,133	100%	1,763	100%	1,926	100%			

[1] Comparison between Pre-COVID (Apr. 2019 - Mar. 16, 2020) and COVID Relaxations (Mar. 16, 2020 - Mar. 2021)
[2] Comparison between Pre-COVID (Apr. 2019 - Mar. 16, 2020) and COVID Relaxations (Mar. 2021 - Dec. 2021)
[3] Comparison between COVID Relaxations (Mar. 16, 2020 - Mar. 2021) and COVID Relaxations (Mar. 2021 - Dec. 2021)
[a] Significant with at least 95% confidence

Table 4.22: Test for Equality of Proportions of Fatal and Suspected Serios Injury Truck-Involved Crashes by Number of Vehicles and Time Period

Number of Vehicles	Pre-COVID (Apr. 2019 - Mar. 16, 2020)		COVID Relaxations (Low VMT) (Mar. 16, 2020 - Mar. 2021)		COVID Relaxations (Normal VMT) (Mar. 2021 - Dec. 2021)		*p*-value[1]	*p*-value[2]	*p*-value[3]
	Frequency	Proportion of Total	Frequency	Proportion of Total	Frequency	Proportion of Total			
Single Vehicle	35	1.64%	19	1.08%	32	1.66%	0.135	0.959	0.129
Multiple Vehicles	90	4.22%	67	3.80%	101	5.24%	0.508	0.124	**0.036**[a]
Total	125	6%	86	5%	133	7%			

[1] Comparison between Pre-COVID (Apr. 2019 - Mar. 16, 2020) and COVID Relaxations (Mar. 16, 2020 - Mar. 2021)
[2] Comparison between Pre-COVID (Apr. 2019 - Mar. 16, 2020) and COVID Relaxations (Mar. 2021 - Dec. 2021)
[3] Comparison between COVID Relaxations (Mar. 16, 2020 - Mar. 2021) and COVID Relaxations (Mar. 2021 - Dec. 2021)
[a] Significant with at least 95% confidence

4.1.12 Weather Condition

Figure 4.23 shows the proportion and frequency of truck-involved crashes by weather condition and time period and Figure 4.24 shows the proportion and frequency of truck-involved crashes by weather condition, time period, and highest sustained injury severity. Table 4.23 and Table 4.24 present the results of the z-tests of proportions, respectively.

Considering all crashes, there was a significantly lower proportion of crashes that occurred during clear conditions in the low VMT COVID relaxations period compared to the pre-COVID period and the normal VMT COVID relaxations period. There was a significantly higher proportion of crashes that occurred in fog in the low VMT COVID relaxations period compared to the pre-COVID period. Likewise, there was a significantly higher proportion of crashes that occurred in snow in the low VMT COVID relaxations period compared to the pre-COVID period and the normal VMT COVID relaxations period. Lastly, there was a significantly higher proportion of crashes that occurred in smoke in the low VMT COVID relaxations period compared to the pre-COVID period and the normal VMT COVID relaxations period. There was also a significantly higher proportion in the normal VMT COVID relaxations period compared to the pre-COVID period.

Considering only fatal and suspected serious injury crashes, there was a significantly lower proportion of crashes that occurred during clear conditions in the low VMT COVID relaxations period compared to the normal VMT COVID relaxations period. There was also a higher proportion in the normal VMT COVID relaxations period compared to the pre-COVID, but at a lower significance threshold (90%).

The proportion of fatal and suspected serious injury crashes that occurred in fog was significantly higher in the low VMT COVID relaxations period compared to the pre-COVID period, and at a lower significance threshold (90%), a higher proportion in the normal VMT COVID relaxations period compared to the pre-COVID period.

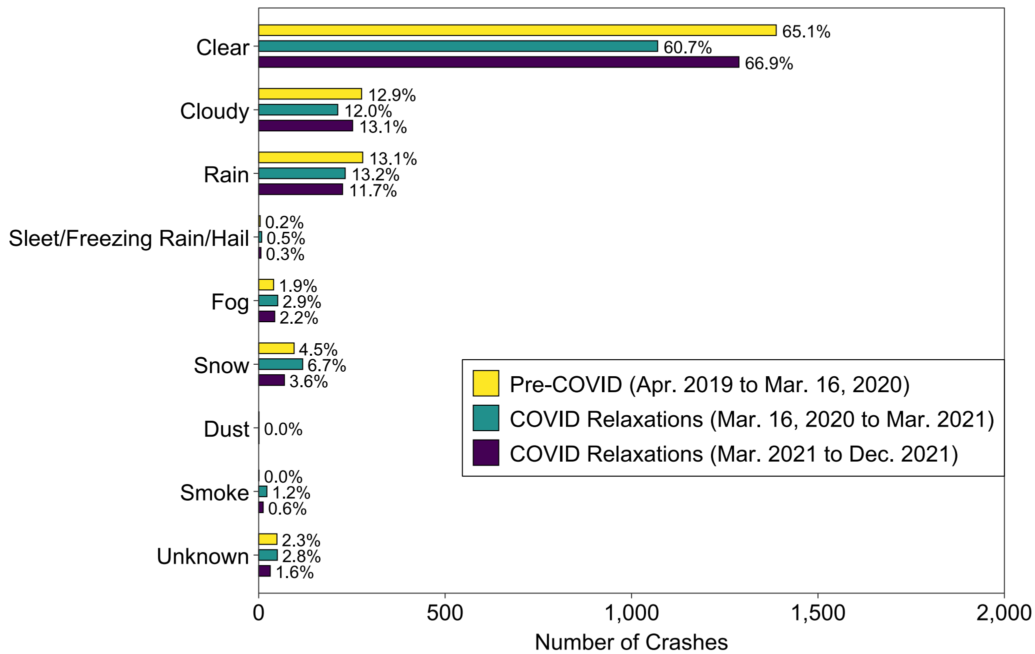

Figure 4.23: Frequency and Proportion of Truck-Involved Crashes by Weather Condition and Time Period

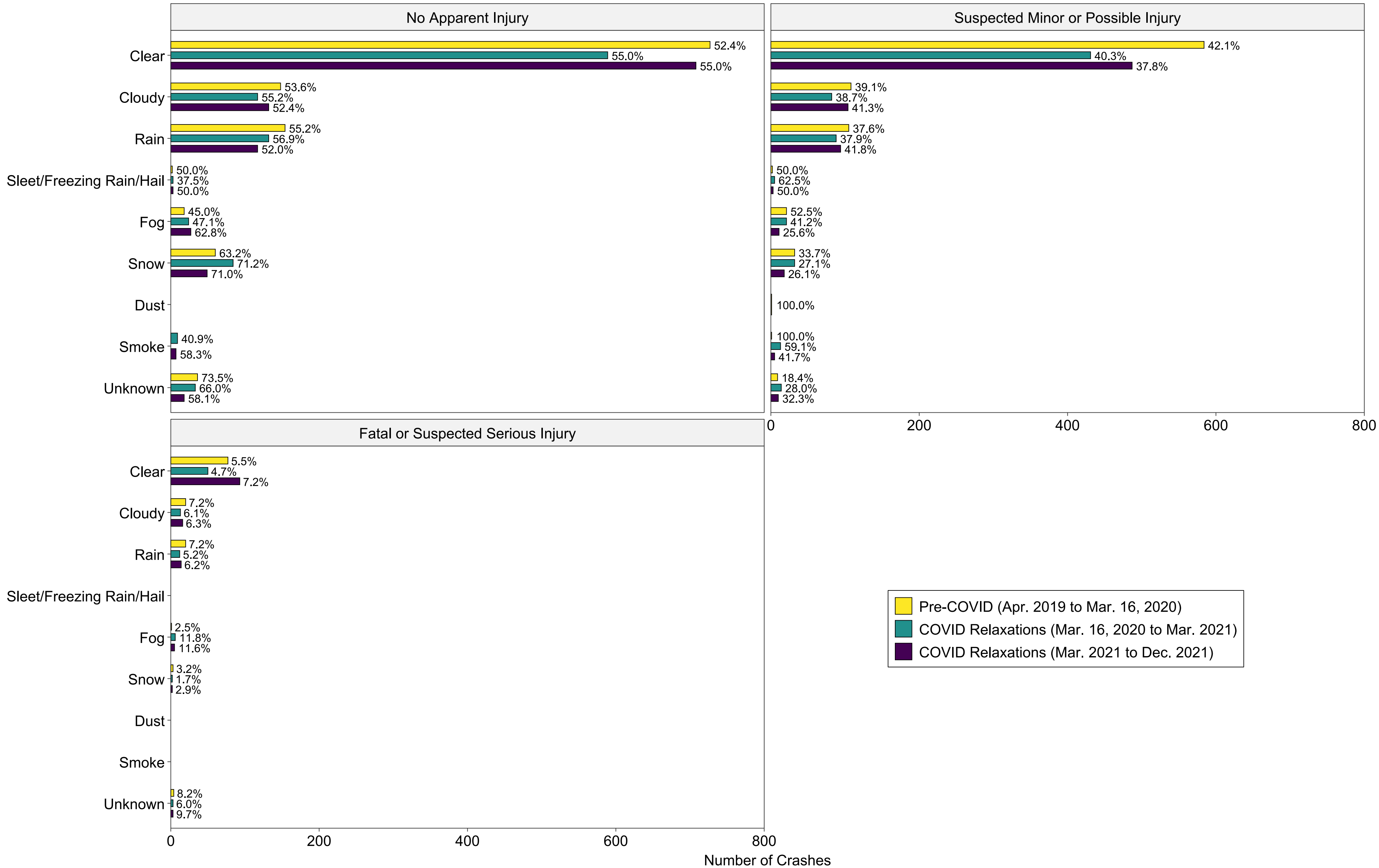

Figure 4.24: Frequency and Proportion of Truck-Involved Crashes by Weather Condition, Time Period, and Highest Sustained Injury Severity

Table 4.23: Test for Equality of Proportions of Truck-Involved Crashes by Weather Condition and Time Period

Weather Condition	Pre-COVID (Apr. 2019 - Mar. 16, 2020)		COVID Relaxations (Low VMT) (Mar. 16, 2020 - Mar. 2021)		COVID Relaxations (Normal VMT) (Mar. 2021 - Dec. 2021)		*p*-value[1]	*p*-value[2]	*p*-value[3]
	Frequency	Proportion of Total	Frequency	Proportion of Total	Frequency	Proportion of Total			
Clear	1,388	65.07%	1,070	60.69%	1,288	66.87%	**0.005[a]**	0.227	**0.000[a]**
Cloudy	276	12.94%	212	12.02%	252	13.08%	0.391	0.891	0.333
Rain	279	13.08%	232	13.16%	225	11.68%	0.942	0.177	0.174
Sleet/Freezing Rain/Hail	4	0.19%	8	0.45%	6	0.31%	0.136	0.426	0.483
Fog	40	1.88%	51	2.89%	43	2.23%	**0.036[a]**	0.422	0.204
Snow	95	4.45%	118	6.69%	69	3.58%	**0.002[a]**	0.159	**0.000a**
Dust	1	0.05%	0	0.00%	0	0.00%	0.363	0.342	NA
Smoke	1	0.05%	22	1.25%	12	0.62%	**0.000[a]**	**0.001[a]**	**0.047[a]**
Unknown	49	2.30%	50	2.84%	31	1.61%	0.287	0.116	**0.011[a]**
Total	2,133		1,763		1,926				

[1] Comparison between Pre-COVID (Apr. 2019 - Mar. 16, 2020) and COVID Relaxations (Mar. 16, 2020 - Mar. 2021)

[2] Comparison between Pre-COVID (Apr. 2019 - Mar. 16, 2020) and COVID Relaxations (Mar. 2021 - Dec. 2021)

[3] Comparison between COVID Relaxations (Mar. 16, 2020 - Mar. 2021) and COVID Relaxations (Mar. 2021 - Dec. 2021)

[a] Significant with at least 95% confidence

[1] Comparison between Pre-COVID (Apr. 2019 - Mar. 16, 2020) and COVID Relaxations (Mar. 16, 2020 - Mar. 2021)

[2] Comparison between Pre-COVID (Apr. 2019 - Mar. 16, 2020) and COVID Relaxations (Mar. 2021 - Dec. 2021)

[3] Comparison between COVID Relaxations (Mar. 16, 2020 - Mar. 2021) and COVID Relaxations (Mar. 2021 - Dec. 2021)

[a] Significant with at least 95% confidence

Table 4.24: Test for Equality of Proportions of Fatal and Suspected Serios Injury Truck-Involved Crashes by Weather Condition and Time Period

Weather Condition	Pre-COVID (Apr. 2019 - Mar. 16, 2020)		COVID Relaxations (Low VMT) (Mar. 16, 2020 - Mar. 2021)		COVID Relaxations (Normal VMT) (Mar. 2021 - Dec. 2021)		*p*-value[1]	*p*-value[2]	*p*-value[3]
	Frequency	Proportion of Total	Frequency	Proportion of Total	Frequency	Proportion of Total			
Clear	77	3.61%	50	2.84%	93	4.83%	0.176	0.053	**0.002**[a]
Cloudy	20	0.94%	13	0.74%	16	0.83%	0.497	0.717	0.748
Rain	20	0.94%	12	0.68%	14	0.73%	0.376	0.462	0.867
Fog	1	0.05%	6	0.34%	5	0.26%	**0.031**[a]	0.078	0.653
Snow	3	0.14%	2	0.11%	2	0.10%	0.813	0.739	0.929
Unknown	4	0.19%	3	0.17%	3	0.16%	0.899	0.808	0.914
Total	125	6%	86	5%	133	7%			

[1] Comparison between Pre-COVID (Apr. 2019 - Mar. 16, 2020) and COVID Relaxations (Mar. 16, 2020 - Mar. 2021)
[2] Comparison between Pre-COVID (Apr. 2019 - Mar. 16, 2020) and COVID Relaxations (Mar. 2021 - Dec. 2021)
[3] Comparison between COVID Relaxations (Mar. 16, 2020 - Mar. 2021) and COVID Relaxations (Mar. 2021 - Dec. 2021)
[a] Significant with at least 95% confidence

4.2 CRASH FREQUENCY ANALYSIS RESULTS

The crash frequency results are presented by the time period model, followed by the holistic model and the transferability test results. For all crash frequency models, that data was not significantly dispersed, thus Poisson models were used. Additionally, there appears to be little unobserved heterogeneity, as no parameters in any of the models were found to be random.

4.2.1 Pre-COVID Period

Model specifications for the pre-COVID crash frequency model are given in Table 4.25.

Results indicate that as traffic volume increases and the proportion of trucks increase, expected crash frequency also increases, with the proportion of trucks having greater effects according to partial effects.

The roadway characteristics that significantly impact crash frequency vary from roadway classifications, roadway geometry, and posted speed limits, where all but one characteristic is expected to decrease expected crash frequency. Both urban and rural arterial segments are expected to decrease crash frequency, as are straight roadway segments, posted speed limits of 20 mi/h or 25 mi/h, and segments with a median barrier. Expected to increase crash frequency are segments that have six or more lanes, which would indicate higher classification roadways that typically have higher posted speed limits and exposure.

Table 4.25: Poisson Specifications for Pre-Covid Crash Frequency Model

Variable	Coeff.	Std. Error	*z*-stat	Partial Effects	Incidence Rate Ratios
Constant	-0.553	0.190	-2.90		
Traffic Volume					
Natural Logarithm of AADT	0.087	0.019	4.61	0.112	
Truck Proportion of AADT	0.570	0.205	2.78	0.738	1.768
Roadway Characteristics					
1 if urban principal arterial classification, 0 otherwise	-0.175	0.042	-4.13	-0.218	0.839
1 if rural minor arterial classification, 0 otherwise	-0.121	0.048	-2.52	-0.149	0.886
1 if straight roadway segment, 0 otherwise	-0.103	0.040	-2.59	-0.133	0.902
1 if six or more lanes, 0 otherwise	0.267	0.138	1.93	0.394	1.307
1 if posted speed limit is 20 mi/h or 25 mi/h, 0 otherwise	-0.123	0.037	-3.32	-0.150	0.885
1 if median barrier, 0 otherwise	-0.228	0.082	-2.76	-0.266	0.796
Model Summary					
Number of observations	847				
Log-likelihood at zero (constant only)	-1035.52				
Log-likelihood at convergence	-1022.24				
McFadden Pseudo R-Squared	0.013				

4.2.2 Low VMT COVID Relaxations Period

The low VMT COVID relaxations period includes crashes from Mar. 16, 2020 to Mar. 2021.

Model specifications for the low VMT COVID relaxations crash frequency model are given in Table 4.26.

Results indicate that as traffic volume increases and the proportion of trucks increase, expected crash frequency also increases, with the proportion of trucks having greater effects according to partial effects.

The roadway characteristics that significantly impact crash frequency vary from roadway classifications, roadway geometry, and posted speed limits, where all but one characteristic is expected to increase expected crash frequency; this is the opposite of what was observed for the pre-COVID model. No urban roadway classifications are significant contributing factors to crash frequency. Rural arterial segments, segments with five or six lanes, and segments with a posted speed limit of 60 mi/h or 65 mi/h are expected to increase crash frequency. Expected to decrease crash frequency are segments with a median barrier.

Table 4.26: Poisson Specifications for Low VMT COVID Relaxations Crash Frequency Model

Variable	Coeff.	Std. Error	*z*-stat	Partial Effects	Incidence Rate Ratios
Constant	-0.764	0.188	-4.06		
Traffic Volume					
Natural Logarithm of AADT	0.091	0.018	5.08	0.125	
Truck Proportion of AADT	0.729	0.243	3.00	0.999	2.073
Roadway Characteristics					
1 if rural principal arterial classification, 0 otherwise	0.150	0.051	2.97	0.213	1.162
1 if rural minor arterial classification, 0 otherwise	0.151	0.070	2.16	0.221	1.163
1 if five or six lane roadway, 0 otherwise	0.215	0.103	2.09	0.323	1.240
1 if median barrier, 0 otherwise	-0.246	0.089	-2.76	-0.301	0.782
1 if posted speed limit is 60 mi/h or 65 mi/h, 0 otherwise	0.120	0.072	1.66	0.170	1.127
Model Summary					
Number of observations	726				
Log-likelihood at zero (constant only)	-922.62				
Log-likelihood at convergence	-910.87				
McFadden Pseudo R-Squared	0.013				

4.2.3 Normal VMT COVID Relaxations Period

The normal VMT COVID relaxations period includes crashes from Mar. 2021 to Dec. 2021.

Model specifications for the normal VMT COVID relaxations crash frequency model are given in Table 4.27.

Results indicate that as traffic volume increases and the proportion of trucks increase, expected crash frequency also increases, with the proportion of trucks having greater effects according to partial effects. The proportion of trucks had the greatest effects in this model, as did overall traffic volume.

Unlike the previous time-period models, the number of significant contributing roadway characteristics is low, with each expected to decrease crash frequency. Urban and rural arterial segments, as well as segments with a raised median, planter, or barrier, are expected to decrease crash frequency.

Table 4.27: Poisson Specifications for Normal VMT COVID Relaxations Crash Frequency Model

Variable	Coeff.	Std. Error	*z*-stat	Partial Effects	Incidence Rate Ratios
Constant	-1.105	0.220	-5.01		
Traffic Volume					
Natural Logarithm of AADT	0.142	0.021	6.79	0.214	
Truck Proportion of AADT	1.498	0.293	5.11	2.257	4.474
Roadway Characteristics					
1 if urban principal arterial classification, 0 otherwise	-0.184	0.051	-3.58	-0.265	0.832
1 if rural minor arterial classification, 0 otherwise	-0.115	0.070	-1.65	-0.165	0.891
1 if raised median, planter, or barrier, 0 otherwise	-0.151	0.066	-2.28	-0.217	0.860
Model Summary					
Number of observations	691				
Log-likelihood at zero (constant only)	-941.94				
Log-likelihood at convergence	-922.37				
McFadden Pseudo R-Squared	0.021				

4.2.4 Holistic Model

Model specifications for the holistic (pooled) crash frequency model are shown in Table 4.28. As discussed in Chapter 4.2.5, separate models should be developed with over 90%; therefore, the intent of this model is not to interpret all explanatory variables. The focus of this model is on the COVID relaxations indicators; specifically, the low VMT COVID relaxations indicator and the normal VMT COVID relaxations indicator.

Relative to the pre-COVID period, crash frequency was expected to increase in the low VMT COVID relaxations period; albeit, marginally. The parameter for the low VMT COVID relaxations period indicator was just significant at the 90% threshold. The normal VMT COVID relaxations period was expected to moderately increase crash frequency relative to the pre-COVID period. The parameter for this indicator was highly significant with well over 99%

confidence. According to model estimates, the effects of the COVID relaxations periods on crash frequency are statistically significant, where both were expected to increase crash frequency.

Table 4.28: Poisson Model Specifications for Holistic (Pooled) Crash Frequency Model

Variable	Coeff.	Std. Error	*z*-stat	Partial Effects	Incidence Rate Ratios
Constant	-0.874	0.117	-7.44		
Traffic Volume					
Natural Logarithm of AADT	0.106	0.011	9.90	0.147	
Truck Proportion of AADT	0.008	0.001	5.20	0.011	1.008
Roadway Characteristics					
1 if rural principal arterial classification, 0 otherwise	0.080	0.034	2.35	0.113	1.083
1 if urban principal arterial classification, 0 otherwise	-0.099	0.029	-3.44	-0.133	0.906
1 if posted speed limit is 20 mi/h or 25 mi/h, 0 otherwise	-0.073	0.042	-1.74	-0.097	0.930
1 if posted speed limit is 60 mi/h or 65 mi/h, 0 otherwise	0.076	0.041	1.84	0.108	1.079
1 if median barrier, 0 otherwise	-0.165	0.057	-2.89	-0.212	0.848
1 if one-way, 0 otherwise	-0.079	0.046	-1.73	-0.106	0.924
COVID Relaxation Period					
1 if low VMT COVID relaxations period, 0 otherwise	0.048	0.029	1.66	0.067	1.049
1 if normal VMT COVID relaxations period, 0 otherwise	0.160	0.031	5.16	0.228	1.173
Model Summary					
Number of observations	2,264				
Log-likelihood at zero (constant only)	-2906.17				
Log-likelihood at convergence	-2863.50				
McFadden Pseudo R-squared	0.015				

4.2.5 Transferability Results

The transferability test given in Eq. (3.23) results in a chi-square statistic of 16.02 with 10 degrees of freedom, indicating that with over 90% confidence, the parameters are not temporally transferable (i.e., the factors affecting crash frequency behavior are different by time period).

Results from the parameter transferability test given in Eq. (3.24) are shown in Table 4.29. In conjunction with the first parameter transferability test, these results indicate that the parameters are not temporally stable across time periods and the null hypothesis that the parameters are the same is rejected with at least 90% (higher for some pairs). This indicates that developing separate models by time period is the appropriate approach.

Table 4.29: Chi-Square Statistics and Degrees of Freedom for Crash Frequency Transferability Test

a	*b*		
	Pre-COVID	**COVID Relaxations (Low VMT)**	**COVID Relaxations (Normal VMT)**
Pre-COVID	---	12.94 (7)	19.23 (5)
COVID Relaxations (Low VMT)	14.80 (7)	---	18.30 (5)
COVID Relaxations (Normal VMT)	13.54 (7)	12.26 (7)	---

4.3 CRASH RATE ANALYSIS

The crash rate results are presented by the time period model, followed by the holistic model and the transferability test results. There appears to be little unobserved heterogeneity, as no parameters in any of the models were found to be random.

4.3.1 Pre-COVID Period

Model specifications for the pre-COVID crash rate model are given in Table 4.30.

As traffic volume increases, crash rate is expected to decrease. Additionally, low ranges of truck traffic is expected to decrease crash rate compared to high ranges of truck traffic. This is opposite of what was observed with expected crash frequency.

Roadway classifications are significant contributing factors to crash rate, where higher rural classification are expected to increase crash rate and lower classifications expected to decrease crash rate. All urban roadway classifications are expected to increase crash rate.

Posted speed limit is also a significant contributing factor to crash rate, where segments with lower posted speed limits are expected to increase crash rate and segments with higher posted speed limits expected to decrease crash rate. This is opposite to what crash frequency analyses typically indicate.

The final segment-level characteristics to significantly contribute to crash rate are the number of lanes, where segments with fewer lanes are expected to decrease crash rate while segments with more lanes are expected to increase crash rate.

Table 4.30: Tobit Model Specifications for Pre-COVID Crash Rate Model

Variable	Coeff.	Std. Error	z-stat	Partial Effects
Constant	35.501	2.054	17.28	
Traffic Volume				
Natural Logarithm of AADT	-3.842	0.225	-17.08	-2.320
1 of truck AADT is between 5,000 and 10,000, 0 otherwise	-1.759	0.871	-2.02	-1.062
Roadway Classification				
1 if rural interstate, 0 otherwise	11.105	1.052	10.56	6.704
1 if rural minor arterial, 0 otherwise	-2.372	0.837	-2.83	-1.432
1 if urban interstate, 0 otherwise	6.724	0.794	8.47	4.059
1 if urban freeway/expressway, 0 otherwise	6.006	1.367	4.39	3.626
1 if urban principal arterial, 0 otherwise	1.862	0.659	2.83	1.124
Posted Speed Limit				
1 if posted speed limit is 30 mi/h or 35 mi/h, 0 otherwise	1.629	0.740	2.20	0.984
1 if posted speed limit is 40 mi/h or 45 mi/h, 0 otherwise	2.340	0.726	3.22	1.413
1 if posted speed limit is 60 mi/h or 65 mi/h, 0 otherwise	-2.040	0.661	-3.09	-1.232
1 if posted speed limit is 70 mi/h, 0 otherwise	-7.957	1.097	-7.26	-4.804
Segment Characteristics				
1 if segment has one or two lanes, 0 otherwise	-2.662	0.532	-5.01	-1.607
1 if segment has five or six lanes, 0 otherwise	2.091	0.961	2.18	1.263
1 if segment has more than six lanes, 0 otherwise	3.034	1.589	1.91	1.832
σ	6.004	0.146	41.01	
Model Summary				
Number of observations	847			
Log-likelihood at zero (constant only)	-2,888.95			
Log-likelihood at convergence	-2,719.07			
Maddala Pseudo R-squared	0.330			

4.3.2 Low VMT COVID Relaxations Period

Model specifications for the low VMT COVID relaxations crash rate model are given in Table 4.31.

As traffic volume increases, crash rate is expected to decrease. Additionally, low ranges of truck traffic is expected to decrease crash rate compared to high ranges of truck traffic.

Roadway classifications are significant contributing factors to crash rate, where higher rural classifications are expected to increase crash rate and lower classifications expected to decrease crash rate. Only one urban classification was found to be a significant contributing factor, and like the pre-COVID model, it is expected to increase crash rate (urban interstate segments).

Only one posted speed limit was found to be a significant contributing factor: posted speed limit of 70 mi/h (observed in Eastern Oregon). Similar to findings in the pre-COVID model, this higher posted speed limit is expected to decrease crash rate.

The segment-level characteristics that significantly contributed to crash rate during this period were noticeably different than those in the pre-COVID model. Specifically, curved segments, segments with a grade, and segments with one or two lanes are expected to decrease crash rate. Expected to increase crash rate are segments with a median barrier and segments with a raised median, planter, or barrier.

Table 4.31: Tobit Model Specifications for Low VMT COVID Relaxations Crash Rate Model

Variable	Coeff.	Std. Error	z-stat	Partial Effects
Constant	42.918	2.936	14.62	
Traffic Volume				
Natural Logarithm of AADT	-4.082	0.235	-17.34	-2.387
1 if truck AADT is between 0 and 5,000, 0 otherwise	-2.211	1.162	-1.90	-1.293
1 if truck AADT is between 5,000 and 10,000, 0 otherwise	-4.371	1.071	-4.08	-2.557
Roadway Classification				
1 if rural interstate, 0 otherwise	4.756	1.003	4.74	2.782
1 if rural principal arterial, 0 otherwise	-3.804	0.591	-6.44	-2.225
1 if rural minor arterial, 0 otherwise	-5.175	0.805	-6.43	-3.027
1 if rural major collector, 0 otherwise	-8.019	1.282	-6.26	-4.690
1 if urban interstate, 0 otherwise	2.455	0.816	3.01	1.436
Posted Speed Limit				
1 if posted speed limit is 70 mi/h, 0 otherwise	-3.485	0.892	-3.91	-2.038
Segment Characteristics				
1 if curved segment, 0 otherwise	-1.281	0.596	-2.15	-0.749
1 if has a grade, 0 otherwise	-3.131	0.695	-4.50	-1.831
1 if segment has one or two lanes, 0 otherwise	-2.101	0.475	-4.42	-1.229
1 if segment has a median barrier, 0 otherwise	4.487	1.135	3.95	2.624
1 if segment has a raised median, planter, or barrier, 0 otherwise	1.299	0.709	1.83	0.760
σ	5.246	0.138	38.00	
Model Summary				
Number of observations	726			
Log-likelihood at zero (constant only)	-2,388.77			
Log-likelihood at convergence	-2,233.45			
Maddala Pseudo R-squared	0.348			

4.3.3 Normal VMT COVID Relaxations Period

Model specifications for the normal VMT COVID relaxations crash rate model are given in Table 4.32.

Like the previous crash rate models, as traffic volume increases, crash rate is expected to decrease. In addition, high ranges of truck volume are expected to increase crash rate compared to lower ranges of truck volume.

Roadway classifications are significant contributing factors to crash rate, where higher rural classifications are expected to increase crash rate and lower classifications expected to decrease crash rate (rural interstate segments increase, while rural arterial and collector segments decrease). All urban classifications identified as significant contributing crash rate factors are expected to increase crash rate (urban interstate segments and urban freeway/expressway segments).

Once more, posted speed limit was found to be a significant contributing factor. Specifically, lower posted speed limits are expected to increase crash rate compared to higher posted speed limits, which are results that have been consistent across models.

The segment-level characteristics that significantly contributed to crash rate during this period were also noticeably different than those in the pre-COVID model. Specifically, segments with a low number of lanes (one or two) are expected to decrease crash rate, while segments with a high number of lanes are expected to increase crash rate. Segments in which a bridge structure is present are expected to increase crash rate, as are segments in which a stop sign is present. Segments that have an intersection are expected to decrease crash rate.

Table 4.32: Tobit Model Specifications for Normal VMT COVID Relaxations Crash Rate Model

Variable	Coeff.	Std. Error	z-stat	Partial Effects
Constant	40.314	2.200	18.32	
Traffic Volume				
Natural Logarithm of AADT	-4.095	0.217	-18.90	-2.552
1 if truck AADT is greater than 10,000, 0 otherwise	1.751	1.002	1.75	1.091
Roadway Classification				
1 if rural interstate, 0 otherwise	3.860	0.758	5.09	2.405
1 if rural principal arterial, 0 otherwise	-3.665	0.642	-5.70	-2.284
1 if rural minor arterial, 0 otherwise	-4.178	0.855	-4.89	-2.603
1 if rural major collector, 0 otherwise	-6.866	1.322	-5.19	-4.278
1 if urban interstate, 0 otherwise	3.271	0.761	4.30	2.039
1 if urban freeway/expressway, 0 otherwise	4.924	1.162	4.24	3.069
Posted Speed Limit				
1 if posted speed limit is 30 mi/h or 35 mi/h, 0 otherwise	2.378	0.672	3.54	1.482

1 if posted speed limit is 40 mi/h or 45 mi/h, 0 otherwise	1.248	0.693	1.80	0.778
Segment Characteristics				
1 if segment has one or two lanes, 0 otherwise	-2.660	0.541	-4.92	-1.658
1 if segment has five or six lanes, 0 otherwise	1.739	0.979	1.78	1.084
1 if segment has a bridge structure, 0 otherwise	4.956	1.447	3.43	3.089
1 if intersection, 0 otherwise	-1.455	0.638	-2.28	-0.907
1 if stop sign, 0 otherwise	1.311	0.767	1.71	0.817
σ	5.053	0.136	37.12	
Model Summary				
Number of observations	691			
Log-likelihood at zero (constant only)	-2,271.12			
Log-likelihood at convergence	-2,099.91			
Maddala R-Squared	0.391			

4.3.4 Holistic Model

Model specifications for the holistic (pooled) crash rate model are shown in Table 4.33. As discussed in Chapter 4.3.5, separate models should be developed with well over 99%; therefore, the intent of this model is not to interpret all explanatory variables. The focus of this model is on the COVID relaxations indicators; specifically, the low VMT COVID relaxations indicator and the normal VMT COVID relaxations indicator.

Relative to the pre-COVID period, crash rate was expected to decrease in the low VMT COVID relaxations period. The parameter for the low VMT COVID relaxations period indicator is not statistically significant. The normal VMT COVID relaxations period was expected to increase crash rate relative to the pre-COVID period. The parameter for this indicator was not statistically significant. According to model estimates, the effects of the COVID relaxations periods on crash rate are not statistically significant.

Table 4.33: Tobit Model Specifications for Holistic (Pooled) Crash Rate Model

Variable	Coeff.	Std. Error	*z*-stat	Partial Effects
Constant	57.654	2.688	21.45	
Traffic Volume				
Natural Logarithm of AADT	-5.502	0.215	-25.57	-3.174
1 if truck AADT is between 0 and 5,000, 0 otherwise	-4.608	1.025	-4.50	-2.658
1 if truck AADT is between 5,000 and 10,000, 0 otherwise	-5.832	0.924	-6.31	-3.364
Roadway Classification				
1 if rural interstate, 0 otherwise	8.768	0.956	9.17	5.058
1 if rural major collector, 0 otherwise	-8.871	1.236	-7.18	-5.117
1 if rural minor arterial, 0 otherwise	-5.437	0.778	-6.98	-3.136
1 if rural principal arterial, 0 otherwise	-3.160	0.595	-5.31	-1.823
1 if urban freeway/expressway, 0 otherwise	5.849	1.172	4.99	3.374
1 if urban interstate, 0 otherwise	4.831	0.753	6.42	2.787
Posted Speed Limit				
1 if posted speed limit is 30 mi/h or 35 mi/h, 0 otherwise	1.978	0.634	3.12	1.141
1 if posted speed limit is 40 mi/h or 45 mi/h, 0 otherwise	2.276	0.637	3.57	1.313
1 if posted speed limit is 60 mi/h or 65 mi/h, 0 otherwise	-1.785	0.564	-3.17	-1.030
1 if posted speed limit is 70 mi/h, 0 otherwise	-5.649	0.922	-6.12	-3.258
Segment Characteristics				
1 if curved segment, 0 otherwise	-1.883	0.575	-3.28	-1.086
1 if segment has a grade, 0 otherwise	-2.714	0.631	-4.30	-1.566
1 if segment has one or two lanes, 0 otherwise	-2.920	0.434	-6.72	-1.685
1 if segment has a raised median, planter, or barrier, 0 otherwise	2.617	0.609	4.30	1.510
1 if no traffic control device, 0 otherwise	1.021	0.552	1.85	0.589
COVID Relaxation Period				
1 if low VMT COVID relaxations period, 0 otherwise	-0.372	0.423	-0.88	-0.214
1 if normal VMT COVID relaxations period, 0 otherwise	0.163	0.429	0.38	0.094
σ	8.308	0.124	67.20	
Model Summary				
Number of observations	2,264			
Log-likelihood at zero (constant only)	-8,371.21			
Log-likelihood at convergence	-8,005.46			
Maddala R-Squared	0.276			

4.3.5 Transferability Results

The transferability test given in Eq. (3.23) results in a chi-square statistic of 1,906.07 with 23 degrees of freedom, indicating with well over 99% confidence that the parameters are not temporally transferable (i.e., the factors affecting crash rate behavior are different by time period).

Results from the parameter transferability test given in Eq. (3.24) are shown in Table 4.29. In conjunction with first parameter transferability test, these results indicate that the parameters are not temporally stable across time periods and the null hypothesis that the parameters are the same is rejected with well over 99% confidence. This indicates that developing separate models by time period is the appropriate approach.

Table 4.34: Chi-Square Statistics and Degrees of Freedom for Crash Rate Transferability Test

a	***b***		
	Pre-COVID	**COVID Relaxations (Low VMT)**	**COVID Relaxations (Normal VMT)**
Pre-COVID	---	153.66 (14)	163.39 (15)
COVID Relaxations (Low VMT)	78.12 (13)	---	76.00 (15)
COVID Relaxations (Normal VMT)	216.17 (13)	218.12(14)	---

4.4 INJURY SEVERITY ANALYSIS

The injury severity results are presented by the time period model, followed by the holistic model and the transferability test results. There was some amount of unobserved heterogeneity, as each injury severity had at least one random parameter.

4.4.1 Pre-COVID Period

Model specifications for the pre-COVID model are shown in Table 4.35 and corresponding marginal effects shown in Table 4.36. In this model, 39 crash characteristics were determined to be significant contributing factors to injury severity outcomes. Possible and fatal injury severity outcomes are explained by the largest number of crash characteristics. Across the 39 crash characteristics, 40% reduce the probability of an injury severity outcome and 60% increase the probability of an injury severity outcome.

In addition, there was some unobserved heterogeneity present, as three parameters were found to be random based on the significance of the standard deviation. All random parameters in the pre-COVID model follow a normal distribution.

The characteristics with random parameters are crashes that occurred in rural areas (serious injury outcomes), if traffic signals were present (possible injury outcomes), and if the truck had no trailers (minor injury outcomes). To interpret these results, both the mean estimate and the standard deviation estimation shown in Table 4.35 are used.

The parameter for if the crash occurred in a rural area has a significant random parameter with mean -0.483 and standard deviation 1.924. This indicates that for 40.1% of crashes that occurred in a rural area, there was a higher likelihood of a serious injury, and for 59.9% of crashes there was a lower likelihood of a serious injury.

The parameter for traffic signals has a significant random parameter with mean 1.101 and standard deviation 2.143. This indicates that 30.4% of crashes in which a traffic signal was present were less likely to result in a minor injury and 69.6% of crashes were more likely to result in a minor injury.

The parameter for truck with no trailers has a significant random parameter with mean -1.367 and standard deviation 2.141, suggesting that for 26.2% of crashes that involved a truck with no trailers were more likely to result in minor injuries and 73.8% were less likely to result in minor injuries.

Regarding the use of safety devices, one characteristic was a significant contributing factor to fatal outcomes and one characteristic to possible injury outcomes. If a safety device was not equipped, marginal effects suggest a higher probability of a fatal outcome, while if the airbag did not deploy there was a lower probability of a possible injury.

For crash types, one explained fatal outcomes, one explained serious injury outcomes, one explained minor injury outcomes, and six explained possible injury outcomes. If the crash was head-on, marginal effects indicate a higher probability of a fatal outcome. If the crash occurred with both vehicles traveling straight and meeting in the opposite direction, marginal effects indicate a higher probability of a serious injury outcome. If the crash was a sideswipe crash in which the two vehicles were meeting, marginal effects suggest a higher probability of a minor injury outcome. For possible injury outcomes, the following crash types, according to marginal effects, result in a lower probability of such an outcome: angle crashes, head-on crashes, fixed-object crashes, crashes with pedestrians, crashes in which the truck overturned, and crashes in which both vehicles were traveling in the opposite direction where one was turning left and the other going straight. Sideswipe crashes where the vehicles were meeting, according to marginal effects, have a higher probability of resulting in a possible injury.

Crash causes were found to be significant contributing factors for fatal and possible injury outcomes only. For fatal crashes, if the driver was inattentive or if the driver ran off the road, marginal effects indicate a higher probability of a fatal outcome. Regarding possible injury outcomes, if the driver followed too closely, made an improper change of lanes, failed to avoid vehicle ahead, or was carelessly driving, marginal effects indicate a higher probability of a possible injury outcome. If the driver was recklessly driving, marginal effects suggest a lower probability of a possible injury outcome.

For temporal characteristics, crashes that occurred in the fall (September through November) had a higher probability of a fatal outcome. Crashes that occurred on a weekday had a lower probability of a serious injury outcome. Lastly, crashes that occurred in the spring (March through May) had a lower probability of a possible injury outcome.

Driver characteristics explain all injury severity outcomes but possible injury. For fatal outcomes, there was a higher probability if the driver was an Oregon resident that was more than 25 miles from home and a lower probability if the driver was not under the influence of marijuana at the time of the crash. For serious injury outcomes, there was a higher probability if the driver was 55 years old to 64 years old. For minor injury outcomes, there was a lower probability if the driver was 65 years old or greater and a lower probability if the driver was not licensed in Oregon.

Roadway and environmental characteristics explained all injury severity outcomes. For fatal outcomes, there was a higher probability if the posted speed limit was 40 mi/h or 45 mi/h and a higher probability if the crash occurred during rainy weather. If the crash occurred during daylight, there was a lower probability of a fatal outcome. For serious injury outcomes, there was a higher probability if the crash occurred on a roadway with five or six lanes. For minor injury outcomes, there was a lower probability if the crash occurred on an urban local road. Lastly, for possible injury outcomes, there was a higher probability if the crash occurred during snowy weather.

Traffic control devices explained serious injury outcomes, where there was a higher probability if the traffic control device was a stop sign and a higher probability if the traffic control device was a median barrier.

Vehicle characteristics explained fatal outcomes. If the truck had one trailing unit, there was a higher probability of a fatal outcome. Likewise, if the truck had two or three trailing units, there was a higher probability of a fatal outcome.

Table 4.35: Mixed Logit Model Specifications for Pre-COVID Injury Severity Model

Variable	Fatal Injury			Serious Injury			Minor Injury			Possible Injury		
	Coeff.	Std. Error	*t*-stat	Coeff.	Std. Error	*t*-stat	Coeff.	Std. Error	*t*-stat	Coeff.	Std. Error	*t*-stat
Constant	—	—	—	2.096	0.733	2.858	4.125	0.626	6.585	4.901	0.629	7.790
Safety Device												
1 if airbag did not deploy, 0 otherwise	—	—	—	—	—	—	—	—	—	-0.365	0.164	-2.226
1 if no safety device equipped, 0 otherwise	2.053	0.711	2.887	—	—	—	—	—	—	—	—	—
Crash Type												
1 if angle, 0 otherwise	—	—	—	—	—	—	—	—	—	-1.071	0.363	-2.947
1 if head-on, 0 otherwise	2.951	0.656	4.499	—	—	—	—	—	—	-1.100	0.594	-1.852
1 if sideswipe (meeting), 0 otherwise	—	—	—	—	—	—	3.249	1.161	2.799	2.243	1.160	1.933
1 if fixed-object, 0 otherwise	—	—	—	—	—	—	—	—	—	-1.102	0.268	-4.113
1 if pedestrian, 0 otherwise	—	—	—	—	—	—	—	—	—	-3.164	0.813	-3.892
1 if overturned, 0 otherwise	—	—	—	—	—	—	—	—	—	-1.806	0.327	-5.520
1 if opposite direction – both vehicles going straight, 0 otherwise	—	—	—	2.201	0.645	3.414	—	—	—	—	—	—
1 if opposite direction – one vehicle turning left and one vehicle going straight, 0 otherwise	—	—	—	—	—	—	—	—	—	-1.445	0.543	-2.662
Crash Cause												
1 if driver followed too closely, 0 otherwise	—	—	—	—	—	—	—	—	—	0.968	0.399	2.428
1 if driver was inattentive, 0 otherwise	1.081	0.577	1.872	—	—	—	—	—	—	—	—	—
1 if driver was recklessly driving, 0 otherwise	—	—	—	—	—	—	—	—	—	-1.099	0.603	-1.823
1 if driver made improper change of traffic lanes, 0 otherwise	—	—	—	—	—	—	—	—	—	0.915	0.375	2.440
1 if driver failed to avoid vehicle ahead, 0 otherwise	—	—	—	—	—	—	—	—	—	1.192	0.337	3.536
1 if driver was carelessly driving, 0 otherwise	—	—	—	—	—	—	—	—	—	1.615	0.592	2.727
1 if driver ran off the road, 0 otherwise	1.428	0.735	1.944	—	—	—	—	—	—	—	—	—
Temporal Characteristics												

Variable	Fatal Injury			Serious Injury			Minor Injury			Possible Injury		
	Coeff.	Std. Error	*t*-stat	Coeff.	Std. Error	*t*-stat	Coeff.	Std. Error	*t*-stat	Coeff.	Std. Error	*t*-stat
1 if crash occurred March to May, 0 otherwise	—	—	—	—	—	—	—	—	—	-0.459	0.205	-2.240
1 if crash occurred September to November, 0 otherwise	1.283	0.377	3.406	—	—	—	—	—	—	—	—	—
1 if crash occurred on a weekday, 0 otherwise	—	—	—	-0.647	0.384	-1.682	—	—	—	—	—	—
Driver Characteristics												
1 if 55 years to 64 years, 0 otherwise	—	—	—	0.643	0.329	1.955	—	—	—	—	—	—
1 if 65 years or greater, 0 otherwise	—	—	—	—	—	—	-0.621	0.332	-1.869	—	—	—
1 if driver not licensed in Oregon, 0 otherwise	—	—	—	—	—	—	-0.498	0.182	-2.741	—	—	—
1 if drive was Oregon resident more than 25 miles from home, 0 otherwise	0.863	0.392	2.203	—	—	—	—	—	—	—	—	—
1 if driver was not under the influence of marijuana, 0 otherwise	-1.023	0.375	-2.724	—	—	—	—	—	—	—	—	—
Roadway and Environmental Characteristics												
1 if roadway classification was urban local, 0 otherwise	—	—	—	—	—	—	-1.927	0.920	-2.094	—	—	—
1 if crash occurred in a rural area, 0 otherwise	—	—	—	-0.483	1.002	-0.482	—	—	—	—	—	—
(Standard deviation of normally distributed parameter)				*(1.924)*	*(1.084)*	*(1.775)*						
1 if crash occurred during daylight conditions, 0 otherwise	-0.851	0.363	-2.345	—	—	—	—	—	—	—	—	—
1 if roadway had five or six lanes, 0 otherwise	—	—	—	1.094	0.421	2.598	—	—	—	—	—	—
1 if posted speed limit was 40 mi/h or 45 mi/h, 0 otherwise	2.363	0.481	4.910	—	—	—	—	—	—	—	—	—
1 if crash occurred during rainy weather, 0 otherwise	1.384	0.435	3.182	—	—	—	—	—	—	—	—	—
1 if crash occurred during snowy weather, 0 otherwise	—	—	—	—	—	—	—	—	—	1.172	0.421	2.782

Variable	Fatal Injury			Serious Injury			Minor Injury			Possible Injury		
	Coeff.	Std. Error	*t*-stat	Coeff.	Std. Error	*t*-stat	Coeff.	Std. Error	*t*-stat	Coeff.	Std. Error	*t*-stat
Traffic Control Device												
1 if traffic signals, 0 otherwise	—	—	—	—	—	—	—	—	—	1.101	0.617	1.785
(Standard deviation of normally distributed parameter)										*(2.143)*	*(1.190)*	*(1.801)*
1 if stop sign, 0 otherwise	—	—	—	0.976	0.394	2.478	—	—	—	—	—	—
1 if one way street, 0 otherwise	—	—	—	—	—	—	—	—	—	—	—	—
1 if median barrier, 0 otherwise	—	—	—	1.268	0.570	2.226	—	—	—	—	—	—
Vehicle Characteristics												
1 if truck had no trailers, 0 otherwise	—	—	—	—	—	—	-1.367	0.745	-1.835	—	—	—
(Standard deviation of normally distributed parameter)							*(2.141)*	*(1.173)*	*(1.825)*			
1 if truck had one trailing unit, 0 otherwise	1.615	0.448	3.605	—	—	—	—	—	—	—	—	—
1 if truck had two or three trailing units, 0 otherwise	2.621	0.844	3.105	—	—	—	—	—	—	—	—	—
Model Summary												
Number of observations	1,025											
Log-likelihood at zero (constants only)	-1,028.45											
Log-likelihood at convergence	-860.82											
McFadden Pseudo R-squared	0.163											

Table 4.36: Marginal Effects for Pre-COVID Injury Severity Model

Variable	Fatal Injury				Serious Injury				Minor Injury				Possible Injury			
	Possible	Minor	Serious	Fatal	Possible	Minor	Serious	Fatal	Possible	Minor	Serious	Fatal	Possible	Minor	Serious	Fatal
Safety Device																
1 if airbag did not deploy, 0 otherwise	—	—	—	—	—	—	—	—	—	—	—	—	-0.0273	0.0199	0.0049	0.0025
1 if not equipped, 0 otherwise	-0.0022	-0.0020	-0.0008	0.0050	—	—	—	—	—	—	—	—	—	—	—	—
Crash Type																
1 if angle, 0 otherwise	—	—	—	—	—	—	—	—	—	—	—	—	-0.0110	0.0072	0.0029	0.0009
1 if head-on, 0 otherwise	-0.0040	-0.0042	-0.0046	0.0129	—	—	—	—	—	—	—	—	-0.0053	0.0018	0.0020	0.0015
1 if sideswipe (meeting), 0 otherwise	—	—	—	—	—	—	—	—	-0.0289	0.0312	-0.0022	-0.0001	0.0216	-0.0200	-0.0016	-0.0001
1 if fixed-object, 0 otherwise	—	—	—	—	—	—	—	—	—	—	—	—	-0.0211	0.0150	0.0038	0.0024
1 if pedestrian, 0 otherwise	—	—	—	—	—	—	—	—	—	—	—	—	-0.0063	0.0034	0.0018	0.0011
1 if overturned, 0 otherwise	—	—	—	—	—	—	—		—	—	—	—	-0.0208	0.0155	0.0034	0.0019
1 if opposite direction – both vehicles going straight, 0 otherwise	—	—	—	—	-0.0057	-0.0052	0.0144	-0.0035	—	—	—	—	—	—	—	—
1 if opposite direction – one vehicle turning left and one vehicle going straight, 0 otherwise	—	—	—	—	—	—	—	—	—	—	—	—	-0.0060	0.0044	0.0011	0.0005
Crash Cause																
1 if driver followed too closely, 0 otherwise	—	—	—	—	—	—	—	—	—	—	—	—	0.0074	-0.0057	-0.0012	-0.0005
1 if driver was inattentive, 0 otherwise	-0.0023	-0.0016	-0.0004	0.0042	—	—	—	—	—	—	—	—	—	—	—	—
1 if driver was recklessly driving, 0 otherwise	—	—	—	—	—	—	—	—	—	—	—	—	-0.0033	0.0024	0.0006	0.0003
1 if driver made improper change of traffic lanes, 0 otherwise	—	—	—	—	—	—	—	—	—	—	—	—	0.0076	-0.0055	-0.0014	-0.0007

Variable	Fatal Injury				Serious Injury				Minor Injury				Possible Injury			
	Possible	Minor	Serious	Fatal	Possible	Minor	Serious	Fatal	Possible	Minor	Serious	Fatal	Possible	Minor	Serious	Fatal
1 if driver failed to avoid vehicle ahead, 0 otherwise	—	—	—	—	—	—	—	—	—	—	—	—	0.0138	-0.0102	-0.0027	-0.0009
1 if driver was carelessly driving, 0 otherwise	—	—	—	—	—	—	—	—	—	—	—	—	0.0050	-0.0035	-0.0011	-0.0004
1 if driver ran off the road, 0 otherwise	-0.0017	-0.0013	-0.0004	0.0035	—	—	—	—	—	—	—	—	—	—	—	—
Temporal Characteristics																
1 if crash occurred March to May, 0 otherwise	—	—	—	—	—	—	—	—	—	—	—	—	-0.0156	0.0114	0.0033	0.0010
1 if crash occurred September to November, 0 otherwise	-0.0098	-0.0063	-0.0020	0.0182	—	—	—	—	—	—	—	—	—	—	—	—
1 if crash occurred on a weekday, 0 otherwise	—	—	—	—	0.0173	0.0104	-0.0300	0.0023	—	—	—	—	—	—	—	—
Driver Characteristics																
1 if 55 years to 64 years, 0 otherwise	—	—	—	—	-0.0053	-0.0036	0.0096	-0.0006	—	—	—	—	—	—	—	—
1 if 65 years or greater, 0 otherwise	—	—	—	—	—	—	—	—	0.0051	-0.0067	0.0008	0.0007	—	—	—	—
1 if driver not licensed in Oregon, 0 otherwise	—	—	—	—	—	—	—	—	0.0220	-0.0277	0.0036	0.0021	—	—	—	—
1 if drive was Oregon resident more than 25 miles from home, 0 otherwise	-0.0041	-0.0037	-0.0011	0.0089	—	—	—	—	—	—	—	—	—	—	—	—
1 if driver was not under the influence of marijuana, 0 otherwise	0.0087	0.0077	0.0023	-0.0186	—	—	—	—	—	—	—	—	—	—	—	—
Roadway and Environmental Characteristics																
1 if roadway classification was urban local, 0 otherwise	—	—	—	—	—	—	—	—	0.0021	-0.0028	0.0006	0.0001	—	—	—	—
1 if crash occurred in a rural area, 0 otherwise	—	—	—	—	-0.0168	-0.0118	0.0304	-0.0019	—	—	—	—	—	—	—	—

Variable	Fatal Injury				Serious Injury				Minor Injury				Possible Injury			
	Possible	Minor	Serious	Fatal	Possible	Minor	Serious	Fatal	Possible	Minor	Serious	Fatal	Possible	Minor	Serious	Fatal
1 if crash occurred during daylight conditions, 0 otherwise	0.0077	0.0051	0.0019	-0.0147	—	—	—	—	—	—	—	—	—	—	—	—
1 if roadway had five or six lanes, 0 otherwise	—	—	—	—	-0.0067	-0.0028	0.0100	-0.0005	—	—	—	—	—	—	—	—
1 if posted speed limit was 40 mi/h or 45 mi/h, 0 otherwise	-0.0082	-0.0055	-0.0016	0.0153	—	—	—	—	—	—	—	—	—	—	—	—
1 if crash occurred during rainy weather, 0 otherwise	-0.0054	-0.0041	-0.0014	0.0108	—	—	—	—	—	—	—	—	—	—	—	—
1 if crash occurred during snowy weather, 0 otherwise	—	—	—	—	—	—	—	—	—	—	—	—	0.0077	-0.0057	-0.0014	-0.0005
Traffic Control Device																
1 if traffic signals, 0 otherwise	—	—	—	—	—	—	—	—	—	—	—	—	0.0034	-0.0032	0.0001	-0.0003
1 if stop sign, 0 otherwise	—	—	—	—	-0.0065	-0.0036	0.0109	-0.0008	—	—	—	—	—	—	—	—
1 if one way street, 0 otherwise	—	—	—	—	—	—	—		—	—	—	—	—	—	—	—
1 if median barrier, 0 otherwise	—	—	—	—	-0.0034	-0.0016	0.0053	-0.0003	—	—	—	—	—	—	—	—
Vehicle Characteristics																
1 if truck had no trailers, 0 otherwise	—	—	—	—	—	—	—	—	0.0011	-0.0028	0.0013	0.0004	—	—	—	—
1 if truck had one trailing unit, 0 otherwise	-0.0181	-0.0149	-0.0040	0.0369	—	—	—	—	—	—	—	—	—	—	—	—
1 if truck had two or three trailing units, 0 otherwise	-0.0023	-0.0023	-0.0006	0.0051	—	—	—	—	—	—	—	—	—	—	—	—

4.4.2 Low VMT COVID Relaxations Period

Model specifications for the pre-COVID model are shown in Table 4.37 and corresponding marginal effects shown in Table 4.38. In this model, 29 crash characteristics were determined to be significant contributing factors to injury severity outcomes. Fatal injury severity outcomes are explained by the largest number of crash characteristics.

In addition, there was some unobserved heterogeneity present, as one parameter was found to be random based on the significance of the standard deviation. The random parameter in the low VMT COVID relaxations model follows a normal distribution.

The parameter for crashes in which two vehicles were traveling in the same direction and both were going straight has a significant random parameter with mean 1.936 and standard deviation 3.896. This suggests that for 31% of crashes in which two vehicles were traveling in the same direction and both going straight there was a decreased likelihood of a possible injury outcome, while for 69% there was an increased likelihood of a possible injury outcome.

Regarding the use of safety devices, if no safety device was equipped, there was a higher probability of a serious injury outcome.

For crash types, one explained fatal outcomes, two explained minor injury outcomes, and one explained possible injury outcomes. If two vehicles were traveling in opposite direction and both were going straight, there was a higher probability of a fatal outcome. For minor injury outcomes, there was a lower probability if two vehicles were traveling in opposite direction, and both were going straight, and a higher probability of the crash was off the roadway. There was a lower probability of a possible injury outcome if the crash was head-on.

Crash causes were found to be significant contributing factors to all injury severity outcomes. If the driver was speeding too fast for conditions (not exceeding the speed limit), there was a higher probability of a fatal outcome. If the driver ran off the roadway, there was a higher probability of a serious injury outcome. If the driver was recklessly driving, there was a higher probability of a minor injury outcome. Lastly, if the driver was exceeding the posted speed limit, there was a lower probability of a possible injury outcome.

For temporal characteristics, crashes that occurred in spring (March through May), there was a higher probability of a fatal outcome. There was also a higher probability of a fatal outcome if the crash occurred in summer (June through August). If the crash occurred on a weekend, there was a lower probability of a possible injury outcome.

Driver characteristics explain fatal and serious injury outcomes. There was a higher probability of a fatal outcome if the driver was 55 years to 64 years old. If the driver was not licensed in Oregon, there was a lower probability of a serious injury outcome.

Roadway and environmental characteristics explained all injury severity outcomes. For fatal outcomes, four characteristics are significant contributing factors, where three increase the probability of a fatal outcome. If the crash occurred on a rural arterial (principal or minor), there was a higher probability of a fatal outcome. If the crash occurred in a work zone, there was also a higher probability of a fatal outcome. If the crash occurred on a dry roadway surface, there was a lower probability of a fatal outcome. For serious injury outcomes, if the crash occurred at an intersection, there was a lower probability of a serious injury. Four characteristics are significant contributing factors to minor injury outcomes, where three of them decrease the probability of a minor injury outcome. If the crash occurred on an urban collector, if the crash occurred at dark with streetlights, and if the crash occurred on a roadway with a posted speed limit of 60 mi/h or 65 mi/h all had a lower probability of a minor injury outcome. If the crash occurred where there was an earth or grass median, there was a higher probability of a minor injury outcome. For possible injury outcomes, if the crash occurred on a roadway with a posted speed limit of 40 mi/h or 45 mi/h, there was a higher probability of a possible injury outcome.

Traffic control devices explained serious injury outcomes and possible injury outcomes. For serious injury outcomes, if there was a stop sign, there was a higher probability of a serious injury outcome. There was a higher probability for possible injury outcomes if there was a traffic signal and there was a higher probability for possible injury outcomes if there was a median barrier.

Vehicle characteristics explained fatal and serious injury outcomes. If the truck had no trailers, there was a higher probability of a fatal outcome. If the truck had two or three trailing units, there was a higher probability of a serious injury outcome.

Table 4.37: Mixed Logit Model Specifications for Low VMT COVID Relaxations Injury Severity Model

Variable	Fatal Injury			Serious Injury			Minor Injury			Possible Injury		
	Coeff.	Std. Error	*t*-stat	Coeff.	Std. Error	*t*-stat	Coeff.	Std. Error	*t*-stat	Coeff.	Std. Error	*t*-stat
Constant	—	—	—	2.208	0.549	4.023	3.887	0.514	7.558	4.113	0.512	8.039
Safety Device												
1 if no safety device equipped, 0 otherwise	—	—	—	1.415	0.709	1.995	—	—	—	—	—	—
Crash Type												
1 if head-on, 0 otherwise	—	—	—	—	—	—	—	—	—	-1.620	0.495	-3.276
1 if same direction – both vehicles going straight, 0 otherwise	—	—	—	—	—	—	—	—	—	1.936	1.040	1.862
(Standard deviation of normally distributed parameter)	—	—	—	—	—	—	—	—	—	*(3.896)*	*(2.208)*	*(1.764)*
1 if opposite direction – both vehicles going straight, 0 otherwise	1.262	0.449	2.812	—	—	—	-0.591	0.342	-1.729	—	—	—
1 if off-roadway, 0 otherwise	—	—	—	—	—	—	0.493	0.214	2.307	—	—	—
Crash Cause												
1 if driver sped too fast for conditions (not exceeding limit), 0 otherwise	1.094	0.445	2.456	—	—	—	—	—	—	—	—	—
1 if driver was driving in excess of posted speed limit, 0 otherwise	—	—	—	—	—	—	—	—	—	-1.729	0.778	-2.221
1 if driver was recklessly driving, 0 otherwise	—	—	—	—	—	—	1.197	0.512	2.338	—	—	—
1 if driver ran off the road, 0 otherwise	—	—	—	1.480	0.724	2.044	—	—	—	—	—	—
Temporal Characteristics												
1 if crash occurred March to May, 0 otherwise	2.109	0.483	4.363	—	—	—	—	—	—	—	—	—
1 if crash occurred June to August, 0 otherwise	1.430	0.527	2.715	—	—	—	—	—	—	—	—	—
1 if weekend, 0 otherwise	—	—	—	—	—	—	—	—	—	-0.712	0.264	-2.696
Driver Characteristics												
1 if 55 years to 64 years, 0 otherwise	0.810	0.384	2.107	—	—	—	—	—	—	—	—	—
1 if driver not licensed in Oregon, 0 otherwise	—	—	—	-1.140	0.396	-2.878	—	—	—	—	—	—

Variable	Fatal Injury			Serious Injury			Minor Injury			Possible Injury		
	Coeff.	Std. Error	*t*-stat	Coeff.	Std. Error	*t*-stat	Coeff.	Std. Error	*t*-stat	Coeff.	Std. Error	*t*-stat
Roadway and Environmental Characteristics												
1 if roadway classification was rural principal arterial, 0 otherwise	1.005	0.434	2.316	—	—	—	—	—	—	—	—	—
1 if roadway classification was rural minor arterial, 0 otherwise	1.135	0.525	2.162	—	—	—	—	—	—	—	—	—
1 if roadway classification was urban major collector, 0 otherwise	—	—	—	—	—	—	-0.950	0.459	-2.067	—	—	—
1 if earth or grass median separating opposing traffic, 0 otherwise	—	—	—	—	—	—	0.912	0.291	3.138	—	—	—
1 if crash occurred at dark with streetlights, 0 otherwise	—	—	—	—	—	—	-0.809	0.351	-2.304	—	—	—
1 if posted limit was 40 mi/h or 45 mi/h, 0 otherwise	—	—	—	—	—	—	—	—	—	0.672	0.280	2.398
1 if posted limit was 60 mi/h or 65 mi/h, 0 otherwise	—	—	—	—	—	—	-0.932	0.250	-3.734	—	—	—
1 if crash occurred on a dry roadway, 0 otherwise	-1.000	0.449	-2.230	—	—	—	—	—	—	—	—	—
1 if crash occurred at an intersection, 0 otherwise	—	—	—	-1.831	0.739	-2.476						
1 if crash occurred in a work zone, 0 otherwise	1.667	0.717	2.324	—	—	—	—	—	—	—	—	—
Traffic Control Device												
1 if traffic signals, 0 otherwise	—	—	—	—	—	—	—	—	—	0.514	0.267	1.926
1 if stop sign, 0 otherwise	—	—	—	2.346	0.758	3.096	—	—	—	—	—	—
1 if median barrier, 0 otherwise	—	—	—	—	—	—	—	—	—	2.681	0.959	2.795
Trailer Quantity												
1 if truck had no trailers, 0 otherwise	0.733	0.415	1.766	—	—	—	—	—	—	—	—	—
1 if truck had two or three trailing units, 0 otherwise	—	—	—	0.927	0.537	1.726	—	—	—	—	—	—
Model Summary												
Number of observations	833											
Log-likelihood at zero (constants only)	-844.08											

Variable	Fatal Injury			Serious Injury			Minor Injury			Possible Injury		
	Coeff.	Std. Error	*t*-stat	Coeff.	Std. Error	*t*-stat	Coeff.	Std. Error	*t*-stat	Coeff.	Std. Error	*t*-stat
Log-likelihood at convergence	-723.79											
McFadden Pseudo R-squared	0.143											

Table 4.38: Marginal Effects for Low VMT COVID Relaxations Injury Severity Model

Variable	Fatal Injury				Serious Injury				Minor Injury				Possible Injury			
	Possible	Minor	Serious	Fatal	Possible	Minor	Serious	Fatal	Possible	Minor	Serious	Fatal	Possible	Minor	Serious	Fatal
Safety Device																
1 if no safety device equipped, 0 otherwise	—	—	—	—	-0.0016	-0.0019	0.0037	-0.0003	—	—	—	—	—	—	—	—
Crash Type																
1 if head-on, 0 otherwise	—	—	—	—	—	—	—	—	—	—	—	—	-0.0110	0.0061	0.0018	0.0031
1 if same direction – both going straight, 0 otherwise	—	—	—	—	—	—	—	—	—	—	—	—	0.0044	-0.0043	-0.0001	-0.0001
1 if opposite direction – both going straight, 0 otherwise	-0.0076	-0.0072	-0.0022	0.0170	—	—	—	—	0.0053	-0.0104	0.0017	0.0034	—	—	—	—
1 if off-roadway, 0 otherwise	—	—	—	—	—	—	—	—	-0.0158	0.0202	-0.0027	-0.0017	—	—	—	—
Crash Cause																
1 if speed too fast for conditions (not exceeding limit), 0 otherwise	-0.0066	-0.0055	-0.0011	0.0132	—	—	—	—	—	—	—	—	—	—	—	—
1 if driving in excess of posted speed, 0 otherwise	—	—	—	—	—	—	—	—	—	—	—	—	-0.0037	0.0028	0.0006	0.0004
1 if reckless driving, 0 otherwise	—	—	—	—	—	—	—	—	-0.0050	0.0064	-0.0006	-0.0007	—	—	—	
1 if ran off road, 0 otherwise	—	—	—	—	-0.0016	-0.0021	0.0038	-0.0001	—	—	—	—	—	—	—	—
Temporal Characteristics																
1 if crash occurred March to May, 0 otherwise	-0.0116	-0.0102	-0.0019	0.0237	—	—	—	—	—	—	—	—	—	—	—	—
1 if crash occurred June to August, 0 otherwise	-0.0071	-0.0071	-0.0014	0.0157	—	—	—	—	—	—	—	—	—	—	—	—
1 if weekend, 0 otherwise	—	—	—	—	—	—	—	—	—	—	—	—	-0.0160	0.0122	0.0019	0.0019
Driver Characteristics																
1 if 55 years to 64 years, 0 otherwise	-0.0051	-0.0046	-0.0009	0.0106	—	—	—	—	—	—	—	—	—	—	—	—
1 if driver not licensed in Oregon, 0 otherwise	—	—	—	—	0.0050	0.0056	-0.0115	0.0009	—	—	—	—	—	—	—	—

Variable	Fatal Injury				Serious Injury				Minor Injury				Possible Injury			
	Possible	**Minor**	**Serious**	**Fatal**	**Possible**	**Minor**	**Serious**	**Fatal**	**Possible**	**Minor**	**Serious**	**Fatal**	**Possible**	**Minor**	**Serious**	**Fatal**
Roadway and Environmental Characteristics																
1 if roadway classificaiton was rural principal arterial, 0 otherwise	-0.0078	-0.0068	-0.0016	0.0161	—	—	—	—	—	—	—	—	—	—	—	—
1 if roadway classification was rural minor arterial, 0 otherwise	-0.0034	-0.0032	-0.0008	0.0073	—	—	—	—	—	—	—	—	—	—	—	—
1 if roadway classification was urban major collector, 0 otherwise	—	—	—	—	—	—	—	—	0.0043	-0.0057	0.0011	0.0004	—	—	—	—
1 if earth or grass median separating opposing traffic, 0 otherwise	—	—	—	—	—	—	—	—	-0.0163	0.0202	-0.0027	-0.0011	—	—	—	—
1 if crash occurred at dark with streetlights, 0 otherwise	—	—	—	—	—	—	—	—	0.0074	-0.0090	0.0009	0.0007	—	—	—	—
1 if posted limit was 40 mi/h or 45 mi/h, 0 otherwise	—	—	—	—	—	—	—	—	—	—	—	—	0.0124	-0.0096	-0.0017	-0.0011
1 if posted limit was 60 mi/h or 65 mi/h, 0 otherwise	—	—	—	—	—	—	—	—	0.0207	-0.0275	0.0039	0.0030	—	—	—	—
1 if crash occurred on a dry roadway, 0 otherwise	0.0096	0.0088	0.0018	-0.0201	—	—	—	—	—	—	—	—	—	—	—	—
1 if crash occurred at an intersection, 0 otherwise	—	—		—	0.0114	0.0073	-0.0195	0.0007	—	—	—	—	—	—	—	—
1 if crash occurred in a work zone, 0 otherwise	-0.0026	-0.0017	-0.0004	0.0046	—	—	—	—	—	—	—	—	—	—	—	—
Traffic Control Device																
1 if traffic signals, 0 otherwise	—	—	—	—	—	—		—	—	—	—	—	0.0115	-0.0102	-0.0004	-0.0009
1 if stop sign, 0 otherwise	—	—	—	—	-0.0136	-0.0089	0.0235	-0.0009	—	—	—	—	—	—	—	—
1 if median barrier, 0 otherwise	—	—	—	—	—	—	—	—	—	—	—	—	0.0085	-0.0070	-0.0012	-0.0004
Vehicle Characteristics																
1 if truck had no trailers, 0 otherwise	-0.0040	-0.0036	-0.0007	0.0084	—	—	—	—	—	—	—	—	—	—	—	—

Variable	Fatal Injury				Serious Injury				Minor Injury				Possible Injury			
	Possible	Minor	Serious	Fatal	Possible	Minor	Serious	Fatal	Possible	Minor	Serious	Fatal	Possible	Minor	Serious	Fatal
1 if truck had two or three trailing units, 0 otherwise	—	—	—	—	-0.0024	-0.0019	0.0045	-0.0003	—	—	—	—	—	—	—	—

4.4.3 Normal VMT COVID Relaxations Period

Model specifications for the pre-COVID model are shown in Table 4.39 and corresponding marginal effects shown in Table 4.40. In this model, 31 crash characteristics were determined to be significant contributing factors to injury severity outcomes. Possible and serious injury severity outcomes are explained by the largest number of crash characteristics.

In addition, there was some unobserved heterogeneity present, as one parameter was found to be random based on the significance of the standard deviation. The random parameter in the normal VMT COVID relaxations model follows a normal distribution.

The parameter for drivers aged 45 years to 54 years has a significant random parameter with a mean of 0.560 and a standard deviation of 2.089. This suggests that for 39.4% of crashes in which the driver was 45 years to 54 years of age were less likely to result in a possible injury, while for 60.6% of crashes in which the driver was 45 years to 54 years of age were more likely to result in a possible injury.

Regarding the use of safety devices, one characteristic was a significant contributing factor to fatal outcomes and one characteristic to possible injury outcomes. If a safety device was not equipped, marginal effects suggest a higher probability of a fatal outcome, while if the airbag did not deploy there was a lower probability of a possible injury.

For crash types, one explained fatal outcomes, one explained serious injury outcomes, three explained minor injury outcomes, and three explained possible injury outcomes. If two vehicles were traveling in the same direction and both vehicles were going straight, there was a lower probability of a fatal outcome. If there was an angle crash, there was a higher probability of a serious injury outcome. If the crash was head-on or if the crash was with a pedestrian, there was a lower probability of a minor injury outcome and possible injury outcome. If the truck overturned in the crash, there was a higher probability of a minor injury outcome. If the crash was a rear-end crash, there was a higher probability of a possible injury outcome.

Crash causes were found to be significant contributing factors for all injury severity outcomes. If the driver drove left of center on a two-way road, there was a higher probability of a fatal outcome. If the driver followed too closely, was inattentive, or was recklessly driving, there was a higher probability of a serious injury outcome. If the driver was inattentive, there was also a higher probability of a minor injury outcome. If the driver disregarded a traffic signal or was driving in excess of the posted speed limit, there was a lower probability of a possible injury outcome.

For temporal characteristics, crashes that occurred in the fall (September through November) had a higher probability of a fatal outcome. For crashes that occurred in the spring (March through May), there was a lower probability of a minor injury outcome. For crashes that occurred between 5 p.m. and 9 p.m., there was a lower probability of a possible injury outcome.

Driver characteristics explain minor and possible injury severity outcomes. If the driver was not an Oregon resident, there was a higher probability of a minor injury outcome. If the driver was

35 years to 44 years old, there was a higher probability of a possible injury outcome, while if the driver was male, there was a lower probability of a possible injury outcome.

Roadway and environmental characteristics explained all injury severity outcomes. Four characteristics explained fatal outcomes. If the crash occurred on a rural interstate, if the crash occurred on a dry roadway surface, or if the crash occurred in foggy weather, there was a higher probability of a fatal outcome. If the crash occurred on a grade, there was a lower probability of a fatal outcome. Four characteristics also explain serious injury outcomes. If the crash occurred in a rural area, if the crash occurred at dusk or dawn, or if the crash occurred on a roadway with a posted speed limit of 50 mi/h or 55 mi/h, there was a higher probability of a serious injury outcome. If the crash occurred where there was no physical barrier between opposing traffic, there was a lower probability of a serious injury outcome. If the crash occurred on an urban interstate, there was a lower probability of a minor injury outcome. Lastly, if the crash occurred in snowy weather, there was a higher probability of a possible injury outcome.

Traffic control devices explained fatal outcomes, where if the traffic control device was a one-way street, there was a higher probability of a fatal outcome.

Vehicle characteristics explained serious injury outcomes. If the truck had one trailing unit, there was a lower probability of a serious injury outcome.

Table 4.39: Mixed Logit Model Specifications for Normal VMT COVID Relaxations Injury Severity Model

Variable	Fatal Injury			Serious Injury			Minor Injury			Possible Injury		
	Coeff.	Std. Error	*t*-stat	Coeff.	Std. Error	*t*-stat	Coeff.	Std. Error	*t*-stat	Coeff.	Std. Error	*t*-stat
Constant	—	—	—	1.881	0.559	3.362	3.961	0.516	7.671	4.333	0.568	7.632
Crash Type												
1 if angle, 0 otherwise	—	—	—	1.057	0.387	2.728	—	—	—	—	—	—
1 if head-on, 0 otherwise	—	—	—	—	—	—	-1.662	0.433	-3.839	-3.021	0.658	-4.591
1 if rear-end, 0 otherwise	—	—	—	—	—	—	—	—	—	0.436	0.170	2.558
1 if pedestrian, 0 otherwise	—	—	—	—	—	—	-2.833	0.700	-4.044	-2.917	0.773	-3.774
1 if overturned, 0 otherwise	—	—	—	—	—	—	0.767	0.405	1.896	—	—	—
1 if same direction – both vehicles going straight, 0 otherwise	-1.693	0.557	-3.040	—	—	—	—	—	—	—	—	—
Crash Cause												
1 if driver disregarded traffic signal, 0 otherwise	—	—	—	—	—	—	—	—	—	-1.529	0.616	-2.482
1 if driver drove left of center on two-way road, 0 otherwise	1.713	0.485	3.532	—	—	—	—	—	—	—	—	—
1 if driver followed too closely, 0 otherwise	—	—	—	1.150	0.437	2.631	—	—	—	—	—	—
1 if driver was inattentive, 0 otherwise	—	—	—	0.967	0.435	2.225	0.605	0.275	2.195	—	—	—
1 if driver was driving in excess of posted speed limit, 0 otherwise	—	—	—	—	—	—	—	—	—	-2.197	0.997	-2.205
1 if driver was recklessly driving, 0 otherwise	—	—	—	1.738	0.486	3.574	—	—	—	—	—	—
Temporal Characteristics												
1 if crash occurred between 5:00 p.m. and 9:00 p.m., 0 otherwise	—	—	—	—	—	—	—	—	—	-0.491	0.234	-2.098
1 if crash occurred March to May, 0 otherwise	—	—	—	—	—	—	-0.391	0.183	-2.143	—	—	—
1 if crash occurred September to November, 0 otherwise	0.882	0.338	2.606	—	—	—	—	—	—	—	—	—
Driver Characteristics												
1 if 35 years to 44 years, 0 otherwise	—	—	—	—	—	—	—	—	—	0.439	0.197	2.230

Variable	Fatal Injury			Serious Injury			Minor Injury			Possible Injury		
	Coeff.	**Std. Error**	***t*-stat**	**Coeff.**	**Std. Error**	***t*-stat**	**Coeff.**	**Std. Error**	***t*-stat**	**Coeff.**	**Std. Error**	***t*-stat**
1 if 45 years to 54 years, 0 otherwise	—	—	—	—	—	—	—	—	—	0.560	0.264	2.120
(Standard deviation of normally distributed parameter)										*(2.089)*	*(1.155)*	*(1.809)*
1 if male, 0 otherwise	—	—	—	—	—	—	—	—	—	-0.585	0.264	-2.214
1 if not an Oregon resident, 0 otherwise	—	—	—	—	—	—	0.375	0.162	2.319	—	—	—
Roadway and Environmental Characteristics												
1 if roadway classification was rural interstate, 0 otherwise	1.362	0.458	2.973	—	—	—	—	—	—	—	—	—
1 if roadway classification was urban interstate, 0 otherwise	—	—	—	—	—	—	-0.770	0.203	-3.802	—	—	—
1 if crash occurred in a rural area, 0 otherwise	—	—	—	0.738	0.272	2.713	—	—	—	—	—	—
1 if no physical barrier between opposing traffic, 0 otherwise	—	—	—	-0.642	0.297	-2.162	—	—	—	—	—	—
1 if dusk or dawn, 0 otherwise	—	—	—	0.966	0.375	2.574	—	—	—	—	—	—
1 if posted limit was 50 mi/h or 55 mi/h, 0 otherwise	—	—	—	0.470	0.262	1.795	—	—	—	—	—	—
1 if crash occurred on a grade, 0 otherwise	-1.431	0.788	-1.816	—	—	—	—	—	—	—	—	—
1 if crash occurred on a dry roadway, 0 otherwise	1.080	0.448	2.412	—	—	—	—	—	—	—	—	—
1 if crash occurred on a snowy roadway, 0 otherwise	—	—	—	—	—	—	—	—	—	1.312	0.518	2.534
1 if crash occurred in foggy weather, 0 otherwise	2.273	0.741	3.068	—	—	—	—	—	—	—	—	—
Traffic Control Device												
1 if one way street, 0 otherwise	1.610	0.345	4.663	—	—	—	—	—	—	—	—	—
Vehicle Characteristics												
1 if truck had one trailing unit, 0 otherwise	—	—	—	-0.765	0.256	-2.986	—	—	—	—	—	—
Model Summary												
Number of observations	902											

Variable	Fatal Injury			Serious Injury			Minor Injury			Possible Injury		
	Coeff.	Std. Error	*t*-stat	Coeff.	Std. Error	*t*-stat	Coeff.	Std. Error	*t*-stat	Coeff.	Std. Error	*t*-stat
Log-likelihood at zero (constants only)	-1,006.21											
Log-likelihood at convergence	-870.18											
McFadden Pseudo R-Squared	0.135											

Table 4.40: Marginal Effects for Normal VMT COVID Injury Severity Model

Variable	Fatal Injury				Serious Injury				Minor Injury				Possible Injury			
	Possible	Minor	Serious	Fatal	Possible	Minor	Serious	Fatal	Possible	Minor	Serious	Fatal	Possible	Minor	Serious	Fatal
Crash Type																
1 if angle, 0 otherwise	—	—	—	—	-0.0035	-0.0058	0.0099	-0.0005	—	—	—	—	—	—	—	—
1 if head-on, 0 otherwise	—	—	—	—	—	—	—	—	0.0029	-0.0149	0.0061	0.0059	-0.0121	0.0053	0.0033	0.0036
1 if rear-end, 0 otherwise	—	—	—	—	—	—	—	—	—	—	—	—	0.0287	-0.0223	-0.0046	-0.0019
1 if pedestrian, 0 otherwise	—	—	—	—	—	—	—	—	0.0018	-0.0071	0.0030	0.0024	-0.0075	0.0018	0.0033	0.0025
1 if overturned, 0 otherwise	—	—	—	—	—	—	—	—	-0.0042	0.0060	-0.0007	-0.0011	—	—	—	—
1 if same direction – both vehicles going straight, 0 otherwise	0.0034	0.0032	0.0007	-0.0073	—	—	—	—	—	—	—	—	—	—	—	—
Crash Cause																
1 if driver disregarded traffic signal, 0 otherwise	—	—	—	—	—	—	—	—	—	—	—	—	-0.0056	0.0042	0.0011	0.0003
1 if driver drove left of center on two-way road, 0 otherwise	-0.0035	-0.0064	-0.0022	0.0121	—	—	—	—	—	—	—	—	—	—	—	—
1 if driver followed too closely, 0 otherwise	—	—	—	—	-0.0043	-0.0034	0.0081	-0.0004	—	—	—	—	—	—	—	—
1 if driver was inattentive, 0 otherwise	—	—	—	—	-0.0028	-0.0045	0.0078	-0.0005	-0.0084	0.0122	-0.0028	-0.0010	—	—	—	—
1 if driver was driving in excess of posted speed limit, 0 otherwise	—	—	—	—	—	—	—	—	—	—	—	—	-0.0037	0.0031	0.0004	0.0002
1 if driver was recklessly driving, 0 otherwise	—	—	—	—	-0.0034	-0.0047	0.0097	-0.0015	—	—	—	—	—	—	—	—
Temporal Characteristics																
1 if crash occurred between 5:00 p.m. and 9:00 p.m., 0 otherwise	—	—	—	—	—	—	—	—	—	—	—	—	-0.0128	0.0097	0.0022	0.0009
1 if crash occurred March to May, 0 otherwise	—	—	—	—	—	—	—	—	0.0130	-0.0178	0.0031	0.0016	—	—	—	—
1 if crash occurred September to November, 0 otherwise	-0.0059	-0.0083	-0.0025	0.0167	—	—	—	—	—	—	—	—	—	—	—	—

Variable	Fatal Injury				Serious Injury				Minor Injury				Possible Injury			
	Possible	Minor	Serious	Fatal	Possible	Minor	Serious	Fatal	Possible	Minor	Serious	Fatal	Possible	Minor	Serious	Fatal
Driver Characteristics																
1 if 35 years to 44 years, 0 otherwise	—	—	—	—	—	—	—	—	—	—	—	—	0.0174	-0.0134	-0.0027	-0.0014
1 if 45 years to 54 years, 0 otherwise	—	—	—	—	—	—	—	—	—	—	—	—	0.0178	-0.0121	-0.0029	-0.0028
1 if male, 0 otherwise	—	—	—	—	—	—	—	—	—	—	—	—	-0.1043	0.0803	0.0156	0.0083
1 if not an Oregon resident, 0 otherwise	—	—	—	—	—	—	—	—	-0.0213	0.0283	-0.0042	-0.0028	—	—	—	—
Roadway and Environmental Characteristics																
1 if roadway classification was rural interstate, 0 otherwise	-0.0032	-0.0051	-0.0015	0.0098	—	—	—	—	—	—	—	—	—	—	—	—
1 if roadway classification was urban interstate, 0 otherwise	—	—	—	—	—	—	—	—	0.0230	-0.0287	0.0042	0.0014	—	—	—	—
1 if crash occurred in a rural area, 0 otherwise	—	—	—	—	-0.0101	-0.0136	0.0265	-0.0028	—	—	—	—	—	—	—	—
1 if no physical barrier between opposing traffic, 0 otherwise	—	—	—	—	0.0058	0.0083	-0.0163	0.0022	—	—	—	—	—	—	—	—
1 if dusk or dawn, 0 otherwise	—	—	—	—	-0.0039	-0.0045	0.0091	-0.0006	—	—	—	—	—	—	—	—
1 if posted limit was 50 mi/h or 55 mi/h, 0 otherwise	—	—	—	—	-0.0060	-0.0068	0.0140	-0.0012	—	—	—	—	—	—	—	—
1 if crash occurred on a grade, 0 otherwise	0.0007	0.0014	0.0008	-0.0028	—	—	—	—	—	—	—	—	—	—	—	—
1 if crash occurred on a dry roadway, 0 otherwise	-0.0141	-0.0189	-0.0060	0.0390	—	—	—	—	—	—	—	—	—	—	—	—
1 if crash occurred on a snowy roadway, 0 otherwise	—	—	—	—	—	—	—	—	—	—	—	—	0.0063	-0.0052	-0.0008	-0.0003
1 if crash occurred in foggy weather, 0 otherwise	-0.0027	-0.0026	-0.0006	0.0059	—	—	—	—	—	—	—	—	—	—	—	—
Traffic Control Device																

Variable	Fatal Injury				Serious Injury				Minor Injury				Possible Injury			
	Possible	Minor	Serious	Fatal	Possible	Minor	Serious	Fatal	Possible	Minor	Serious	Fatal	Possible	Minor	Serious	Fatal
1 if one way street, 0 otherwise	-0.0087	-0.0116	-0.0040	0.0243	—	—	—	—	—	—	—	—	—	—	—	—
Vehicle Characteristics																
1 if truck had one trailing unit, 0 otherwise	—	—	—	—	0.0113	0.0143	-0.0284	0.0027	—	—	—	—	—	—	—	—

4.4.4 Holistic Model

Model specifications for the holistic (pooled) injury severity model are shown in Table 4.41. As discussed in Chapter 4.4.5, separate models should be developed with well over 99% confidence; therefore, the intent of this model is not to interpret all explanatory variables. The focus of this model is on the COVID relaxations indicators; specifically, the low VMT COVID relaxations indicator and the normal VMT COVID relaxations indicator.

Relative to the pre-COVID period, there was a higher probability of a fatal outcome, a lower probability of a serious injury outcome, and a higher probability of a minor injury outcome in the low VMT COVID relaxations period. In the fatal and serious injury severity functions, the parameter for the low VMT COVID relaxations period is not statistically significant. In the minor injury severity function, the parameter is statistically significant.

In the normal VMT COVID relaxations period there was a higher probability of fatal outcomes, serious injury outcomes, and minor injury outcomes relative to the pre-COVID period. The parameter for the normal VMT COVID relaxations parameter is statistically significant in each of the three functions.

According to model estimates, the significant effects on injury severity (relative to the pre-COVID period) were in the normal VMT COVID relaxations period. For each injury severity outcome, there was a higher probability during the normal VMT COVID relaxations period.

Table 4.41: Multinomial Logit Model Specifications for Holistic (Pooled) Injury Severity Model

Variable	Fatal Injury			Serious Injury			Minor Injury			Possible Injury		
	Coeff.	Std. Error	*t*-stat	Coef f.	Std. Error	*t*-stat	Coef f.	Std. Error	*t*-stat	Coef f.	Std. Error	*t*-stat
Constant	—	—	—	-0.903	0.299	-3.02	0.478	0.287	1.67	1.894	0.284	6.68
Safety Device												
1 if airbag deployed, 0 otherwise	—	—	—	—	—	—	—	—	—	-0.714	0.334	-2.14
1 if no safety device equipped, 0 otherwise	0.973	0.415	2.34	—	—	—	—	—	—	—	—	—
1 if seat belt properly fastened, 0 otherwise	—	—	—	—	—	—	0.243	0.121	2.01	—	—	—
Crash Type												
1 if head-on, 0 otherwise	—	—	—	1.305	0.286	4.56	—	—	—	-0.931	0.287	-3.24
1 if backing, 0 otherwise	—	—	—	—	—	—	—	—	—	1.115	0.473	2.36
1 if pedestrian, 0 otherwise	—	—	—	—	—	—	—	—	—	-1.674	0.407	-4.12
1 if overturn, 0 otherwise	—	—	—	—	—	—	1.054	0.206	5.12	—	—	—
1 if rear-end, 0 otherwise	-1.912	0.297	-6.45	—	—	—	—	—	—	—	—	—
1 if turning movement, 0 otherwise	-1.193	0.302	-3.95	—	—	—	—	—	—	—	—	—
1 if sideswipe (overtaking), 0 otherwise	-2.731	0.536	-5.10	—	—	—	—	—	—	—	—	—
1 if fixed-object, 0 otherwise	-1.541	0.335	-4.60	—	—	—	—	—	—	—	—	—
1 if angle, 0 otherwise	-0.653	0.371	-1.76	—	—	—	—	—	—	—	—	—
1 if sideswipe (meeting), 0 otherwise	-1.685	0.479	-3.52	—	—	—	—	—	—	—	—	—
1 if parked vehicle, 0 otherwise	—	—	—	1.001	0.494	2.03	—	—	—	—	—	—
Crash Cause												

Variable	Fatal Injury			Serious Injury			Minor Injury			Possible Injury		
	Coeff.	**Std. Error**	***t*-stat**	**Coeff.**	**Std. Error**	***t*-stat**	**Coeff.**	**Std. Error**	***t*-stat**	**Coeff.**	**Std. Error**	***t*-stat**
1 if driver was speeding too fast for conditions, 0 otherwise	—	—	—	—	—	—	—	—	—	-0.350	0.141	-2.49
1 if driver was exceeding the posted speed limit, 0 otherwise	—	—	—	—	—	—	—	—	—	-0.991	0.340	-2.92
1 if driver drove left of center on a two-way road, 0 otherwise	1.482	0.331	4.48	—	—	—	1.956	0.624	3.13	1.289	0.633	2.04
1 if driver ran off the road, 0 otherwise	—	—	—	1.024	0.423	2.42	—	—	—	-0.796	0.376	-2.12
1 if driver was inattentive, 0 otherwise	—	—	—	—	—	—	0.399	0.159	2.51	—	—	—
1 if driver was driving recklessly, 0 otherwise	—	—	—	1.350	0.380	3.56	1.042	0.305	3.42	—	—	—
1 if driver was fatigued, 0 otherwise	—	—	—	—	—	—	1.065	0.401	2.66	—	—	—
1 if driver was following too close, 0 otherwise	—	—	—	—	—	—	-0.723	0.296	-2.45	—	—	—
1 if driver failed to avoid vehicle ahead, 0 otherwise	—	—	—	-1.387	0.469	-2.96	—	—	—	—	—	—
1 if driver improperly changed lanes, 0 otherwise	—	—	—	-1.799	0.723	-2.49	—	—	—	—	—	—
1 if driver made an improper turn, 0 otherwise	—	—	—	-1.018	0.613	-1.66	—	—	—	—	—	—
Temporal Characteristics												
1 if crash occurred December to February, 0 otherwise	—	—	—	—	—	—	—	—	—	0.235	0.108	2.17
1 if crash occurred on a weekend, 0 otherwise	—	—	—	—	—	—	—	—	—	-0.333	0.129	-2.58
Driver Characteristics												
1 if 25 years to 34 years, 0 otherwise	—	—	—	—	—	—	-0.094	0.275	-0.34	—	—	—
1 if 55 years to 64 years, 0 otherwise	—	—	—	0.342	0.171	2.01	—	—	—	—	—	—

Variable	Fatal Injury			Serious Injury			Minor Injury			Possible Injury		
	Coeff.	Std. Error	*t*-stat	Coeff.	Std. Error	*t*-stat	Coeff.	Std. Error	*t*-stat	Coeff.	Std. Error	*t*-stat
1 if driver was not under the influence of drugs, 0 otherwise	—	—	—	—	—	—	—	—	—	-3.259	0.686	-4.75
1 if driver was licensed in Oregon, 0 otherwise	—	—	—	—	—	—	—	—	—	-0.222	0.091	-2.43
1 if driver was not under the influence of marijuana, 0 otherwise	—	—	—	—	—	—	—	—	—	3.110	0.685	4.54
1 if driver was not under the influence of alcohol, 0 otherwise	—	—	—	—	—	—	-2.660	0.775	-3.43	—	—	—
1 if driver was not under the influence of marijuana, 0 otherwise	—	—	—	—	—	—	2.643	0.772	3.42	—	—	—
Roadway and Environmental Characteristics												
1 if crash occurred on a horizontal cuve, 0 otherwise	—	—	—	—	—	—	—	—	—	-0.358	0.148	-2.42
1 if roadway classification was urban interstate, 0 otherwise	—	—	—	—	—	—	-0.277	0.145	-1.91	—	—	—
1 if roadway classification was rural principal arterial, 0 otherwise	0.568	0.219	2.60	—	—	—	—	—	—	—	—	—
1 if roadway classification was rural minor arterial, 0 otherwise	—	—	—	-0.990	0.354	-2.80	—	—	—	—	—	—
1 if road had five or six lanes, 0 otherwise	—	—	—	—	—	—	-0.582	0.201	-2.89	—	—	—
1 if earth or grass median separating opposing traffic, 0 otherwise	—	—	—	—	—	—	0.462	0.141	3.27	—	—	—
1 if posted speed limit was 40 mi/h or 45 mi/h, 0 otherwise	0.548	0.289	1.89	—	—	—	—	—	—	—	—	—
1 if posted speed limit was 50 mi/h or 55 mi/h, 0 otherwise	—	—	—	0.463	0.161	2.87	—	—	—	—	—	—
1 if posted speed limit was 60 mi/h or 65 mi/h, 0 otherwise	—	—	—	—	—	—	-0.318	0.131	-2.43	—	—	—

Variable	Fatal Injury			Serious Injury			Minor Injury			Possible Injury		
	Coeff.	**Std. Error**	***t*-stat**	**Coeff.**	**Std. Error**	***t*-stat**	**Coeff.**	**Std. Error**	***t*-stat**	**Coeff.**	**Std. Error**	***t*-stat**
1 if crash occurred in daylight, 0 otherwise	-0.549	0.195	-2.82	—	—	—	—	—	—	—	—	—
1 if snowy weather, 0 otherwise	—	—	—	-1.094	0.541	-2.02	—	—	—	—	—	—
1 if snowy weather, 0 otherwise	-1.572	0.665	-2.36	—	—	—	—	—	—	—	—	—
Traffic Control Device												
1 if traffic signal, 0 otherwise	—	—	—	-0.582	0.321	-1.81	—	—	—	—	—	—
1 if stop sign, 0 otherwise	—	—	—	0.777	0.201	3.87	—	—	—	—	—	—
1 if no traffic control, 0 otherwise	0.526	0.251	2.10	—	—	—	—	—	—	—	—	—
Vehicle Characteristics												
1 if truck had no trailers, 0 otherwise	—	—	—	0.538	0.164	3.29	—	—	—	—	—	—
COVID Relaxation Periods												
1 if crash occurred during low VMT COVID relaxations period, 0 otherwise	0.354	0.242	1.46	-0.287	0.204	-1.41	0.353	0.117	3.01	—	—	—
1 if crash occurred during normal VMT COVID relaxations period, 0 otherwise	0.705	0.235	3.00	0.380	0.180	2.11	0.792	0.115	6.90	—	—	—
Model Summary												
Number of observations	2,760											
Log-likelihood at zero (constants only)	-2,907.25											
Log-likelihood at convergence	-2,566.91											
McFadden Pseudo R-Squared	0.117											

Table 4.42: Marginal Effects for Holistic (Pooled) Injury Severity Model

Variable	Fatal Injury				Serious Injury				Minor Injury				Possible Injury			
	Possible	Minor	Serious	Fatal	Possible	Minor	Serious	Fatal	Possible	Minor	Serious	Fatal	Possible	Minor	Serious	Fatal
Safety Device																
1 if airbag deployed, 0 otherwise	—	—	—	—	—	—	—	—	—	—	—	—	-0.0024	0.0016	0.0004	0.0003
1 if no safety device equipped, 0 otherwise	-0.0009	-0.0010	-0.0005	0.0024	—	—	—	—	—	—	—	—	—	—	—	—
1 if seat belt properly fastened, 0 otherwise	—	—	—		—	—	—	—	-0.0270	0.0346	-0.0046	-0.0031	—	—	—	—
Crash Type																
1 if head-on, 0 otherwise	—	—	—	—	-0.0021	-0.0036	0.0086	-0.0029	—	—	—	—	-0.0052	0.0021	0.0015	0.0017
1 if backing, 0 otherwise	—	—	—	—	—	—	—	—	—	—	—	—	0.0020	-0.0012	-0.0004	-0.0004
1 if pedestrian, 0 otherwise	—	—	—	—	—	—	—	—	—	—	—	—	-0.0038	0.0020	0.0006	0.0012
1 if overturn, 0 otherwise	—	—	—	—	—	—	—	—	-0.0072	0.0112	-0.0013	-0.0028	—	—	—	—
1 if rear-end, 0 otherwise	0.0078	0.0038	0.0010	-0.0126	—	—	—	—	—	—	—	—	—	—	—	—
1 if turning movement, 0 otherwise	0.0045	0.0026	0.0007	-0.0077	—	—	—	—	—	—	—	—	—	—	—	—
1 if sideswipe (overtaking), 0 otherwise	0.0025	0.0012	0.0003	-0.0039	—	—	—	—	—	—	—	—	—	—	—	—
1 if fixed-object, 0 otherwise	0.0035	0.0028	0.0009	-0.0072	—	—	—	—	—	—	—	—	—	—	—	—
1 if angle, 0 otherwise	0.0013	0.0008	0.0003	-0.0024	—	—	—	—	—	—	—	—	—	—	—	—
1 if sideswipe (meeting), 0 otherwise	0.0018	0.0012	0.0003	-0.0033	—	—	—	—	—	—	—	—	—	—	—	—
1 if parked vehicle, 0 otherwise	—	—	—		-0.0009	-0.0006	0.0016	-0.0001	—	—	—	—	—	—	—	—
Crash Cause																
1 if driver was speeding too fast for conditions, 0 otherwise	—	—	—	—	—	—	—	—	—	—	—	—	-0.0087	0.0065	0.0014	0.0008
1 if driver was exceeding the posted speed limit, 0 otherwise	—	—	—	—	—	—	—	—	—	—	—	—	-0.0033	0.0023	0.0006	0.0004

Variable	Fatal Injury				Serious Injury				Minor Injury				Possible Injury			
	Possible	Minor	Serious	Fatal	Possible	Minor	Serious	Fatal	Possible	Minor	Serious	Fatal	Possible	Minor	Serious	Fatal
1 if driver drove left of center on a two-way road, 0 otherwise	-0.0030	-0.0035	-0.0020	0.0085	—	—	—	—	-0.0055	0.0068	-0.0004	-0.0010	0.0042	-0.0036	-0.0002	-0.0004
1 if driver ran off the road, 0 otherwise	—	—	—	—	-0.0010	-0.0014	0.0027	-0.0003	—	—	—	—	-0.0026	0.0015	0.0008	0.0003
1 if driver was inattentive, 0 otherwise	—	—	—	—	—	—	—		-0.0057	0.0071	-0.0009	-0.0005	—	—	—	—
1 if driver was driving recklessly, 0 otherwise	—	—	—	—	-0.0016	-0.0030	0.0051	-0.0004	-0.0031	0.0058	-0.0023	-0.0004	—	—	—	—
1 if driver was fatigued, 0 otherwise	—	—	—	—	—	—	—		-0.0020	0.0027	-0.0004	-0.0002	—	—	—	—
1 if driver was following too close, 0 otherwise	—	—	—	—	—	—	—		0.0030	-0.0035	0.0004	0.0001	—	—	—	—
1 if driver failed to avoid vehicle ahead, 0 otherwise	—	—	—	—	0.0018	0.0006	-0.0024	0.0001	—	—	—	—	—	—	—	—
1 if driver improperly changed lanes, 0 otherwise	—	—	—	—	0.0010	0.0003	-0.0013	0.0000	—	—	—	—	—	—	—	—
1 if driver made an improper turn, 0 otherwise	—	—	—	—	0.0006	0.0003	-0.0010	0.0001	—	—	—	—	—	—	—	—
Temporal Characteristics																
1 if crash occurred December to February, 0 otherwise	—	—	—	—	—	—	—	—	—	—	—	—	0.0105	-0.0078	-0.0016	-0.0010
1 if crash occurred on a weekend, 0 otherwise	—	—	—	—	—	—	—	—	—	—	—	—	-0.0089	0.0066	0.0015	0.0008
Driver Characteristics																
1 if 25 years to 34 years, 0 otherwise	—	—	—	—	—	—	—	—	-0.0085	0.0099	-0.0009	-0.0005	—	—	—	—
1 if 55 years to 64 years, 0 otherwise	—	—	—	—	-0.0031	-0.0023	0.0059	-0.0005	—	—	—	—	—	—	—	—
1 if driver was not under the influence of drugs, 0 otherwise	—	—	—	—	—	—	—	—	—	—	—	—	-0.4150	0.3013	0.0725	0.0412

Variable	Fatal Injury				Serious Injury				Minor Injury				Possible Injury			
	Possible	Minor	Serious	Fatal	Possible	Minor	Serious	Fatal	Possible	Minor	Serious	Fatal	Possible	Minor	Serious	Fatal
1 if driver was licensed in Oregon, 0 otherwise	—	—	—	—	—	—	—	—	—	—	—	—	-0.0258	0.0186	0.0046	0.0025
1 if driver was not under the inflence of marijuana, 0 otherwise	—	—	—	—	—	—	—	—	-0.2439	0.3186	-0.0442	-0.0304	0.3942	-0.2871	-0.0684	-0.0388
1 if driver was not under the influence of alcohol, 0 otherwise	—	—	—	—	—	—	—	—	0.2459	-0.3221	0.0451	0.0311	—	—	—	—
Roadway and Environmental Characteristics																
1 if crash occurred on a horizontal cuve, 0 otherwise	—	—	—	—	—	—	—	—	—	—	—	—	-0.0077	0.0056	0.0012	0.0009
1 if roadway classification was urban interstate, 0 otherwise	—	—	—	—	—	—	—	—	0.0075	-0.0089	0.0010	0.0004	—	—	—	—
1 if roadway classification was rural principal arterial, 0 otherwise	-0.0029	-0.0028	-0.0011	0.0067	—	—	—	—	—	—	—	—	—	—	—	—
1 if roadway classification was rural minor arterial, 0 otherwise	—	—	—	—	0.0015	0.0013	-0.0032	0.0004	—	—	—	—	—	—	—	—
1 if road had five or six lanes, 0 otherwise	—	—	—	—	—	—	—	—	0.0074	-0.0086	0.0009	0.0003	—	—	—	—
1 if earth or grass median separating opposing traffic, 0 otherwise	—	—	—	—	—	—	—	—	-0.0113	0.0134	-0.0015	-0.0007	—	—	—	—
1 if posted speed limit was 40 mi/h or 45 mi/h, 0 otherwise	-0.0013	-0.0012	-0.0004	0.0029	—	—	—	—	—	—	—	—	—	—	—	—
1 if posted speed limit was 50 mi/h or 55 mi/h, 0 otherwise	—	—	—	—	-0.0062	-0.0044	0.0118	-0.0012	—	—	—	—	—	—	—	—
1 if posted speed limit was 60 mi/h or 65 mi/h, 0 otherwise	—	—	—	—	—	—	—	—	0.0092	-0.0112	0.0012	0.0008	—	—	—	—

Variable	Fatal Injury				Serious Injury				Minor Injury				Possible Injury			
	Possible	Minor	Serious	Fatal	Possible	Minor	Serious	Fatal	Possible	Minor	Serious	Fatal	Possible	Minor	Serious	Fatal
1 if crash occurred in daylight, 0 otherwise	0.0067	0.0054	0.0019	-0.0141	—	—	—	—	—	—	—	—	—	—	—	—
1 if snowy weather, 0 otherwise	0.0006	0.0005	0.0002	-0.0014	0.0007	0.0005	-0.0014	0.0001	—	—	—	—	—	—	—	—
Traffic Control Device																
1 if traffic signal, 0 otherwise	—	—	—	—	0.0014	0.0008	-0.0024	0.0001	—	—	—	—	—	—	—	—
1 if stop sign, 0 otherwise	—	—	—	—	-0.0054	-0.0034	0.0096	-0.0007	—	—	—	—	—	—	—	—
1 if no traffic control, 0 otherwise	-0.0017	-0.0018	-0.0006	0.0040	—	—	—	—	—	—	—	—	—	—	—	—
Vehicle Characteristics																
1 if truck had no trailers, 0 otherwise	—	—	—	—	-0.0064	-0.0041	0.0115	-0.0010	—	—	—	—	—	—	—	—
COVID Relaxation Periods																
1 if crash occurred during low VMT COVID relaxations period, 0 otherwise	-0.0023	-0.0018	-0.0005	0.0046	0.0024	0.0015	-0.0043	0.0004	-0.0169	0.0206	-0.0019	-0.0018	—	—	—	—
1 if crash occurred during normal VMT COVID relaxations period, 0 otherwise	-0.0044	-0.0049	-0.0016	0.0109	-0.0045	-0.0041	0.0095	-0.0009	-0.0403	0.0544	-0.0086	-0.0055	—	—	—	—

4.4.5 Transferability Results

The transferability test given in Eq. (3.23) results in a chi-square statistic of 224.23 with 43 degrees of freedom, indicating with well over 99% confidence that the parameters are not temporally transferable (i.e., the factors affecting injury severity behavior are different by time period).

Results from the parameter transferability test given in Eq. (3.24) are shown in Table 4.43. In conjunction with the first parameter transferability test, these results indicate that the parameters are not temporally stable across time periods and the null hypothesis that the parameters are the same is rejected with well over 99% confidence. This indicates that developing separate models by time period is the appropriate approach.

Table 4.43: Chi-Square Statistics and Degrees of Freedom for Injury Severity Transferability Test

a	***b***		
	Pre-COVID	**COVID Relaxations (Low VMT)**	**COVID Relaxations (Normal VMT)**
Pre-COVID	---	530.87 (30)	373.73 (34)
COVID Relaxations (Low VMT)	428.11 (38)	---	324.25 (32)
COVID Relaxations (Normal VMT)	536.52 (29)	503.62 (29)	---

4.5 DESCRIPTIVE SUMMARY

A summary of the crash characteristics with significant differences in proportions is given in Table 4.44. The red/green arrows indicate a decrease/increase, respectively, in proportions for the time period specified in the parentheses.

For all crashes, the majority of differences were between the pre-COIVD period and the low VMT COVID relaxations period. Whether the low VMT COVID relaxations period had a significantly higher or lower proportion was dependent on the crash characteristic. The proportions in driver age, driver-level crash causes, and collision types were significantly lower in the low VMT COVID relaxations period. The one exception within these characteristics were fixed-object crashes, where the low VMT COVID relaxations period had a significantly higher proportion. The higher proportions of fixed-object and single vehicle crashes in the low VMT COVID relaxations period are likely linked to exposure, as traffic volume across the U.S. decreased, on average, by 45% to 55% (Du et al., 2021). Substantial reductions were also experienced in Oregon (Oregon Department of Transportation, 2021).

For roadway, environmental, and vehicle characteristics, dry road surface conditions, multiple vehicles, and clear weather had significantly lower proportions in the low VMT COVID relaxations period compared to the pre-COVID period. Icy road surface conditions, snowy road surface conditions, 12 a.m. to 3 a.m., single vehicles, foggy weather, snowy weather, and smoky weather had significantly higher proportions in the low VMT COVID relaxations period. The weather-related characteristics with higher proportions in the low VMT COVID relaxations period are likely linked to the extreme weather events in Oregon in 2020. In the summer, there were homes destroyed, deaths, and approximately 1.1 million acres burned due to wildfires (Hasenstab, 2022). The higher proportion of winter-related conditions is likely linked to the "ice storm" that happened in early 2021 (Jones, 2022; Woodworth, 2022).

For fatal and serious injury crashes, the majority of differences were among the two COVID periods, where all but one characteristic had significantly lower proportions in the low VMT COVID relaxations period (the exception was improper change of traffic lanes).

The significant differences in proportions between the pre-COVID period and the low VMT COVID relaxations period were primarily differences in which proportions in the low VMT COVID relaxations period were lower compared to the pre-COVID period. The one characteristic which had a significantly higher proportion in the low VMT COVID relaxations period was foggy weather.

Table 4.44: Summary of Proportions Tests

Characteristic	All Crashes			Fatal and Serious Injury Crashes		
	Pre-COVID and Low VMT COVID Relaxations	Pre-COVID and Normal VMT COVID Relaxations	Low VMT COVID Relaxations and Normal VMT COVID Relaxations	Pre-COVID and Low VMT COVID Relaxations	Pre-COVID and Normal VMT COVID Relaxations	Low VMT COVID Relaxations and Normal VMT COVID Relaxations
Driver Age						
35 yrs - 44 yrs	↓ (low VMT)	↓ (normal VMT)	—	---	---	---
Driver-Level Crash Cause						
Did Not Yield Right-of-Way	↓ (low VMT)	↓ (normal VMT)	—	—	—	—
Failed to Avoid Vehicle Ahead	↓ (low VMT)	—	↓ (low VMT)	—	—	—
Improper Change of Traffic Lanes	—	↓ (normal VMT)	—	—	↓ (normal VMT)	↑ (low VMT)
Speed Too Fast for Conditions	—	↓ (normal VMT)	—	—	—	—
Inattention	—	—	—	—	—	↓ (low VMT)
Collision Type						
Sideswipe (Overtaking)	↓ (low VMT)	—	—	↓ (low VMT)	—	—
Parked	↓ (low VMT)	↓ (normal VMT)	—	—	—	—
Fixed-Object	↑ (low VMT)	—	↑ (low VMT)	—	—	—
Driver Gender						
Male	—	—	—	—	—	↓ (low VMT)
Lighting Condition						
Dark (No Lights)	—	—	—	↓ (low VMT)	—	—
Older Drivers						
Driver Less than 65 yrs	—	—	—	—	↑ (normal VMT)	↓ (low VMT)
Driver Residence	—	—	—	—	—	—
Oregon Resident (Within 25 Miles of Home)	—	—	—	—	↑ (normal VMT)	↓ (low VMT)
Road Surface Condition						

Characteristic	All Crashes			Fatal and Serious Injury Crashes		
	Pre-COVID and Low VMT COVID Relaxations	Pre-COVID and Normal VMT COVID Relaxations	Low VMT COVID Relaxations and Normal VMT COVID Relaxations	Pre-COVID and Low VMT COVID Relaxations	Pre-COVID and Normal VMT COVID Relaxations	Low VMT COVID Relaxations and Normal VMT COVID Relaxations
Dry	↓ (low VMT)	—	↓ (low VMT)	↓ (low VMT)	—	↓ (low VMT)
Ice	↑ (low VMT)	—	↑ (low VMT)	—	—	—
Snow	↑ (low VMT)	—	↑ (low VMT)	—	—	—
Time-of-Day						
12:00 a.m. - 3:00 a.m.	↑ (low VMT)	↑ (normal VMT)	—	↓ (low VMT)	—	↓ (low VMT)
12:00 p.m. - 3:00 p.m.	—	—	—	—	—	↓ (low VMT)
Vehicles Involved						
Single Vehicle	↑ (low VMT)	—	↑ (low VMT)	—	—	—
Multiple Vehicles	↓ (low VMT)	—	↓ (low VMT)	—	—	↓ (low VMT)
Weather						
Clear	↓ (low VMT)	—	↓ (low VMT)	—	↑ (normal VMT)	↓ (low VMT)
Fog	↑ (low VMT)	—	—	↑ (low VMT)	—	—
Snow	↑ (low VMT)	—	—	—	—	—
Smoke	↑ (low VMT)	—	—	—	—	—

4.6 CRASH FREQUENCY SUMMARY

A summary of the crash frequency contributing factors is given in Table 4.45. A red arrow indicates the crash characteristic increases expected crash frequency and a green arrow indicates the crash characteristic decreases expected crash frequency. A summary of the effects of variables that are in multiple models is shown in Figure 4.25. Note that the plot shows scaled effects, based on the standard deviation of the effects, for illustration purposes. An assessment of the models is given by the CURE plots shown in Figure 4.26. If the line representing the cumulative residuals (the black line) stays within the fitted bounds (red lines) and oscillates about zero, the crash frequency model is said to have good fit over the range of the model (i.e., all crash values) (Monsere et al., 2020). Overall, with a few exceptions, this holds true.

Traffic volume (AADT) and the proportion of trucks increased expected crash frequency in each time period, with the largest effects observed in the normal VMT COVID relaxations period (the low VMT COVID relaxations period had larger effects relative to the pre-COVID period). The increase in expected crash frequency due to traffic volume is well-documented in the literature under various contexts (Park and Lord, 2007; Aguero-Valverde and Jovanis, 2008; Aguero-Valverde, 2013; Ye et al., 2013; Chiou and Fu, 2015; Han et al., 2018; Hou et al., 2018; Taylor et al., 2018). Regarding truck traffic, previous work has also found that as the proportion of truck volume increases so does expected crash frequency (Chang, 2005; Chiou and Fu, 2015; Dong et al., 2017). Although the effect of traffic volume and proportion of trucks were greater in the COVID relaxations periods, increases in crash frequency were expected in all periods.

The effects of roadway classification are notable across the three time period models. Urban principal arterials were significant contributing factors in the pre-COVID model and the normal VMT COVID relaxations model. In both models, urban principal arterials were expected to decrease crash frequency. This classification was not a significant contributing factor in the pre-COVID relaxations model. Urban segments have been found to increase expected crash frequency, which is consistent with this work (Malyshkina and Mannering, 2010; Venkataraman et al., 2011; Zhang et al., 2012). For rural classifications, rural arterials (principal and minor) were expected to increase crash frequency in the low VMT COVID relaxations period, while rural minor arterials were expected to decrease crash frequency in the pre-COVID and normal VMT COVID relaxations period.

Segments with a higher number of lanes were found to increase expected crash frequency in the pre-COVID and low VMT COVID relaxations period, which is consistent with previous work (Chang, 2005; Venkataraman et al., 2011; Barua et al., 2016). Median barriers, during the same two periods, were found to decrease expected crash frequency; this was also a finding in previous work (Malyshkina et al., 2009).

Posted speed limit was a significant contributing factor in the pre-COVID period and the low VMT COVID relaxations period, where lower speed limits were expected to decrease crash frequency (pre-COVID period) and higher posted speed limits were expected to increase crash frequency (low VMT COVID relaxations period. This, too, is consistent with previous studies (Savolainen and Tarko, 2005; Malyshkina et al., 2009; Anastasopoulos, 2016).

Regarding the effects of the COVID relaxations periods, both periods had statistically significant effects and both were expected to increase crash frequency.

Table 4.45: Summary of Crash Frequency Contributing Factors

Variable	Pre-COVID	Low VMT COVID Relaxations	Normal VMT COVID Relaxations
Traffic Volume			
AADT	↑	↑	↑
Truck Proportion of AADT	↑	↑	↑
Roadway Characteristics			
1 if urban principal arterial classification, 0 otherwise	↓	—	↓
1 if rural principal arterial classification, 0 otherwise	—	↑	—
1 if rural minor arterial classification, 0 otherwise	↓	↑	↓
1 if straight roadway segment, 0 otherwise	↓	—	—
1 if five or six lane roadway, 0 otherwise	—	↑	—
1 if six or more lanes, 0 otherwise	↑	—	—
1 if posted speed limit is 60 mi/h or 65 mi/h, 0 otherwise	—	↑	—
1 if posted speed limit is 20 mi/h or 25 mi/h, 0 otherwise	↓	—	—
1 if median barrier, 0 otherwise	↓	↓	—
1 if raised median, planter, or barrier, 0 otherwise	↓	—	—

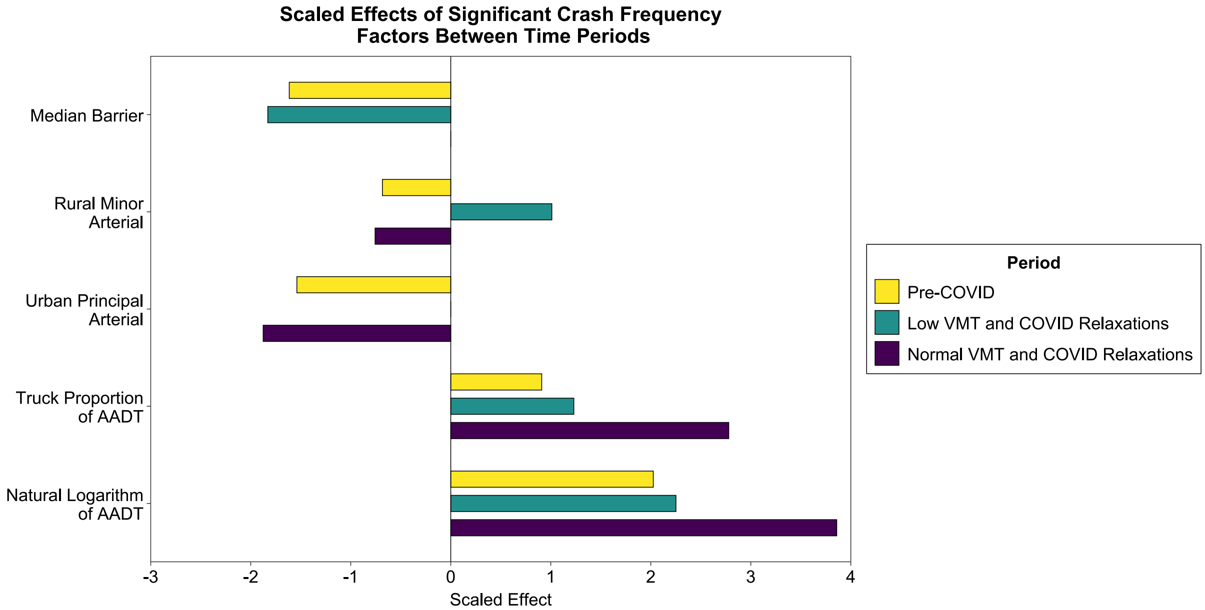

Figure 4.25: Scaled Effects of Significant Crash Frequency Contributing Factors and Time Period

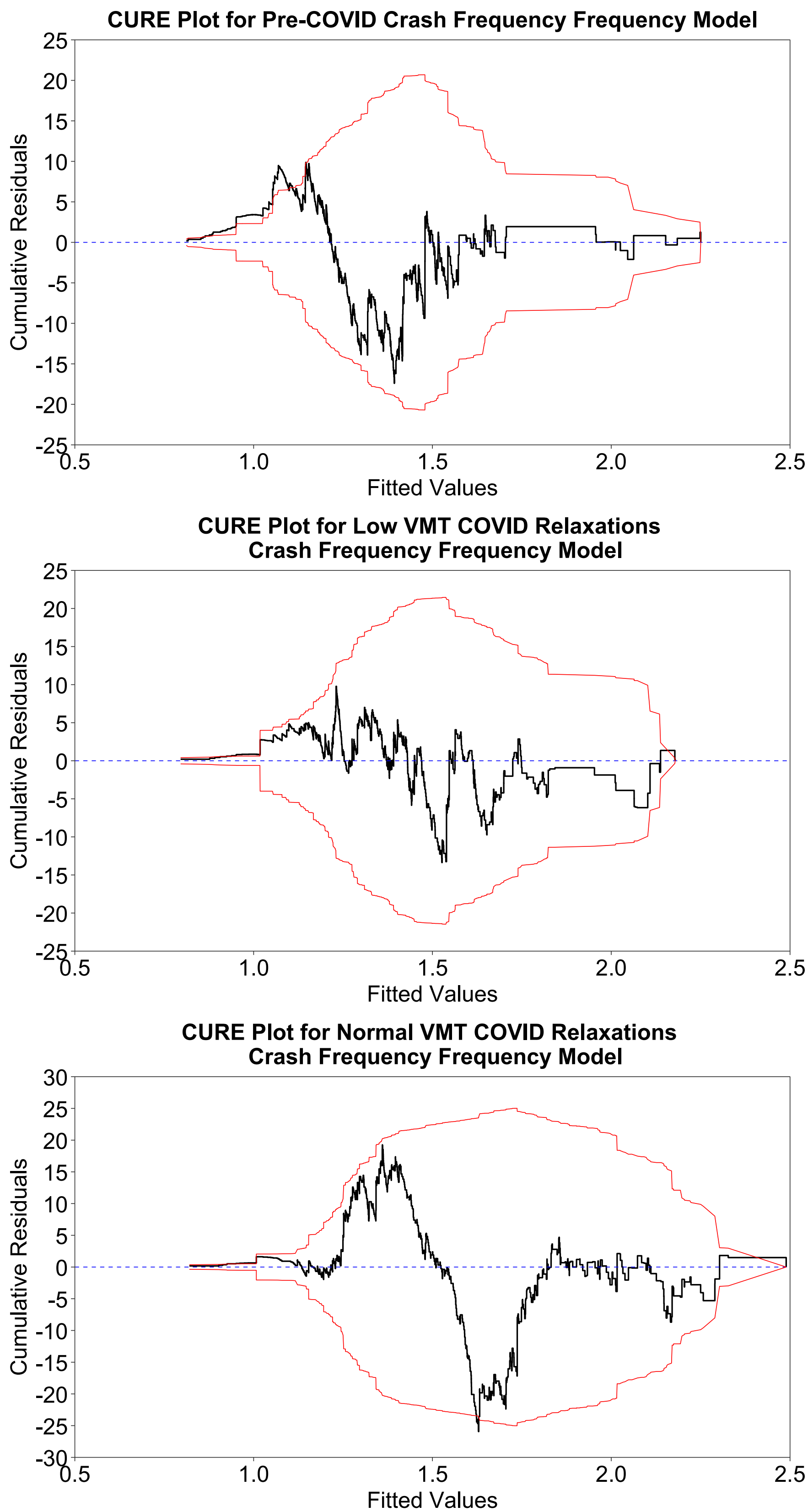

Figure 4.26: CURE Plots for Crash Frequency Models

4.7 CRASH RATE SUMMARY

A summary of the crash rate contributing factors is given in Table 4.46. A red arrow indicates the crash characteristic increases crash rate and a green arrow indicates the crash characteristic decreases crash rate. An assessment of the models is given by the actual vs. fitted value plots shown in Figure 4.27. The plots provide a visual representation of how well the model is fitting the crash rate values. Overall, the models provide decent fit based on Maddala's Pseudo R-square value. A summary of the effects of variables that are in multiple models is shown in Figure 4.28.

Increases in traffic volume (AADT) and lower truck volume decrease crash rate in each time period model. Traffic volume is a significant contributing factor in each model, while significance of ranges of truck traffic varied across time periods. Increases in traffic volume resulting in a decrease in crash rate is well-documented in the crash rate literature (Anastasopoulos et al., 2008, 2012; Anastasopoulos, 2016; Anderson and Hernandez, 2017a) and is consistent with this work. The findings of this study differ regarding the effect of truck traffic on crash rate. Specifically, this work finds that higher truck volume leads to increases in crash rate (lower truck volumes to decreases in crash rate). Previous work, however, has found that as truck volume increases, crash rate decreases (Anastasopoulos et al., 2012; Chen et al., 2014; Anastasopoulos, 2016; Anderson and Hernandez, 2017a). This finding may be specific to the context of this work and may warrant further investigation. The effects of traffic volume (total) and truck volume appear to be consistent across time periods.

The effects of roadway classification are notable across the three time period models. Rural interstates were expected to increase crash rate during each time period, while lower rural classifications were expected to decrease crash rate in the low VMT and normal VMT COVID relaxations periods. With the exception of rural minor arterials, all lower rural classifications were significant contributing factors in only the COVID relaxations time periods. Urban interstates were also expected to increase crash rate across the three time periods. However, unlike rural classifications, all lower urban classifications were also expected to increase crash rate. With the exception of urban interstates, all other urban classifications were significant contributing factors in the pre-COVID model or the normal VMT COVID relaxations model.

Posted speed limit was a significant contributing factor in each of the time periods, where lower speed limits were expected to increase crash rate and higher posted speed limits were expected to decrease crash rate (the opposite effect when considering crash frequency). These findings are consistent with previous studies that have also found segments with higher posted speed limits to decrease crash rate (Chen et al., 2014; Anderson and Hernandez, 2017a).

Curved segments were a significant contributing factor in only the low VMT COVID relaxations period and expected to decrease crash rate. This finding is in contrast with previous work that has found curved segments to increase crash rate (Anastasopoulos, 2016; Anderson and Hernandez, 2017a). Being that the finding in this work is specific to the low VMT COVID relaxations period, this contrast may be attributed to such conditions. Vertical curves (grades) were also found to decrease crash rate only in the low VMT COVID relaxations period. This is consistent with previous work, where Anastasopoulos et al. (2008) found that as the number of vertical curves per mile increases, crash rate decreases.

Segments with a higher number of lanes were found to increase expected crash rate in the pre-COVID and normal VMT COVID relaxations period, which is consistent with previous work (Anastasopoulos, 2016). Segments with a lower number of lanes (one or two) were a significant contributing factor in each time period and decreased expected crash rate.

Median barriers had significant effects on crash rate in the low VMT COVID relaxations period only, where an increase in crash rate was expected. This is in contrast with previous crash rate studies, which found median barriers to decrease crash rate (Anastasopoulos et al., 2008; Islam and Hernandez, 2015). Being that the finding in this work is specific to the low VMT COVID relaxations period, this contrast may be attributed to such conditions.

The remaining characteristics were significant contributing factors in the normal VMT COVID relaxations period, including bridge structures, intersections, and stop signs. Bridge structures were found to increase crash rate, contrasting previous work that found as the number of bridge structures increase, crash rate decreases (Anastasopoulos et al., 2008). Stop signs were found to increase crash rate, where Anderson and Hernandez (2017) also found stop signs to increase crash rate.

Regarding the effects of the COVID relaxations periods, both periods were not statistically significant; however, model estimates did suggest that relative to the pre-COVID period, crash rate was expected to decrease in the low VMT COVID relaxations period and increase in the normal VMT COVID relaxations period.

Table 4.46: Summary of Crash Rate Contributing Factors

Variable	Pre-COVID	Low VMT COVID Relaxations	Normal VMT COVID Relaxations
Traffic Volume			
Natural Logarithm of AADT	↓	↓	↓
1 if truck AADT is between 0 and 5,000, 0 otherwise	—	↓	—
1 of truck AADT is between 5,000 and 10,000, 0 otherwise	↓	↓	—
1 if truck AADT is greater than 10,000, 0 otherwise	—	—	↑
Roadway Characteristics			
1 if rural interstate, 0 otherwise	↑	↑	↑
1 if rural minor arterial, 0 otherwise	↓	↓	↓
1 if urban interstate, 0 otherwise	↑	↑	↑
1 if urban freeway/expressway, 0 otherwise	↑	—	↑
1 if urban principal arterial, 0 otherwise	↑	—	—
1 if rural principal arterial, 0 otherwise	—	↓	↓
1 if rural major collector, 0 otherwise	—	↓	↓
Posted Speed Limit			
1 if posted speed limit is 30 mi/h or 35 mi/h, 0 otherwise	↑	—	↑
1 if posted speed limit is 40 mi/h or 45 mi/h, 0 otherwise	↑	—	↑
1 if posted speed limit is 60 mi/h or 65 mi/h, 0 otherwise	↓	—	—
1 if posted speed limit is 70 mi/h, 0 otherwise	↓	↓	—
Segment Characteristics			
1 if curved segment, 0 otherwise	—	↓	—
1 if segment has a grade, 0 otherwise	—	↓	—
1 if segment has one or two lanes, 0 otherwise	↓	↓	↓
1 if segment has five or six lanes, 0 otherwise	↑	—	↑
1 if segment has more than six lanes, 0 otherwise	↑	—	—
1 if segment has a median barrier, 0 otherwise	—	↑	—
1 if segment has a raised median, planter, or barrier, 0 otherwise	—	↑	—
1 if segment has a bridge structure, 0 otherwise	—	—	↑
1 if intersection, 0 otherwise	—	—	↓
1 if stop sign, 0 otherwise	—	—	↑

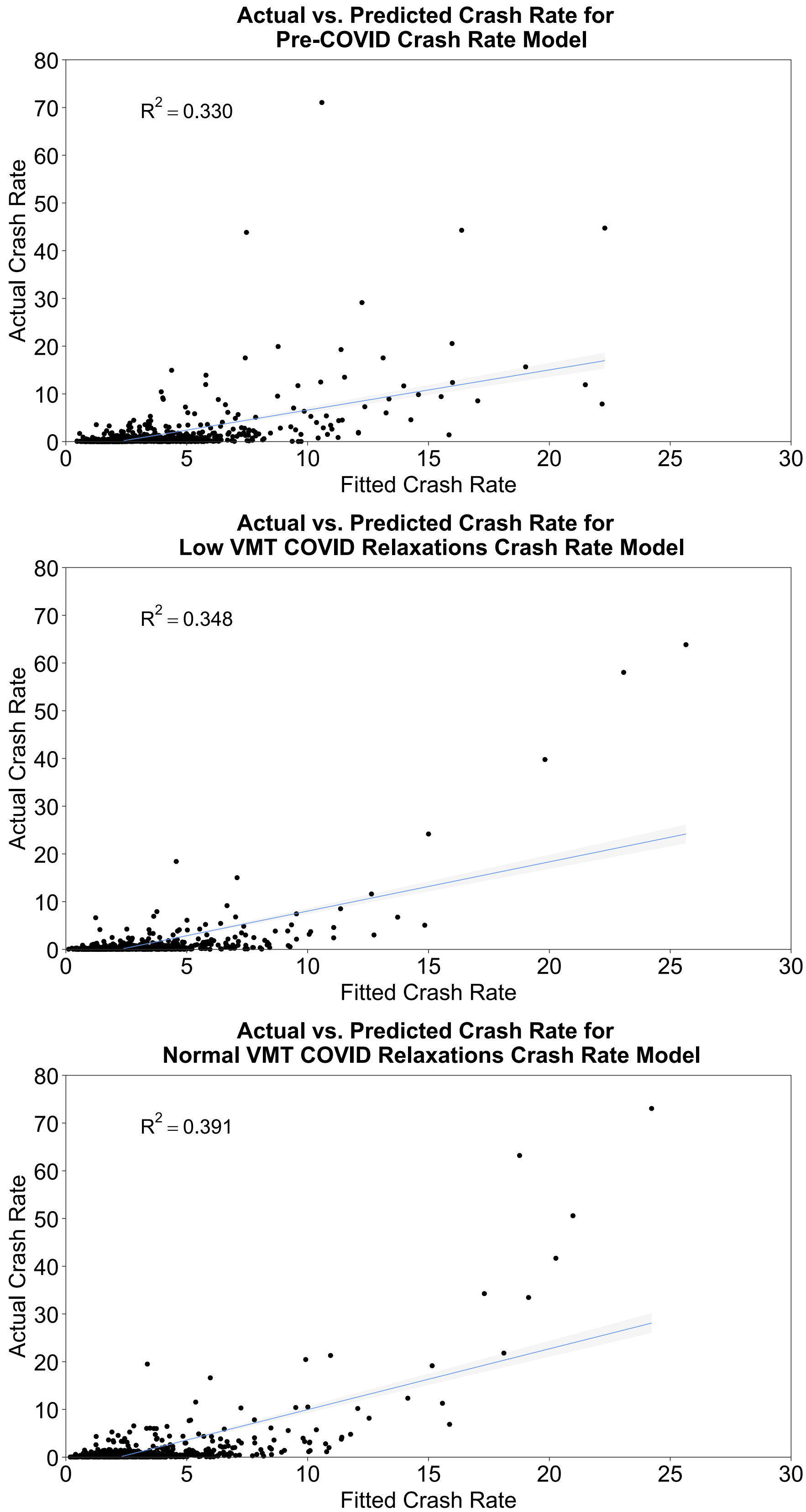

Figure 4.27: Actual vs. Fitted Plots for Crash Rate Models

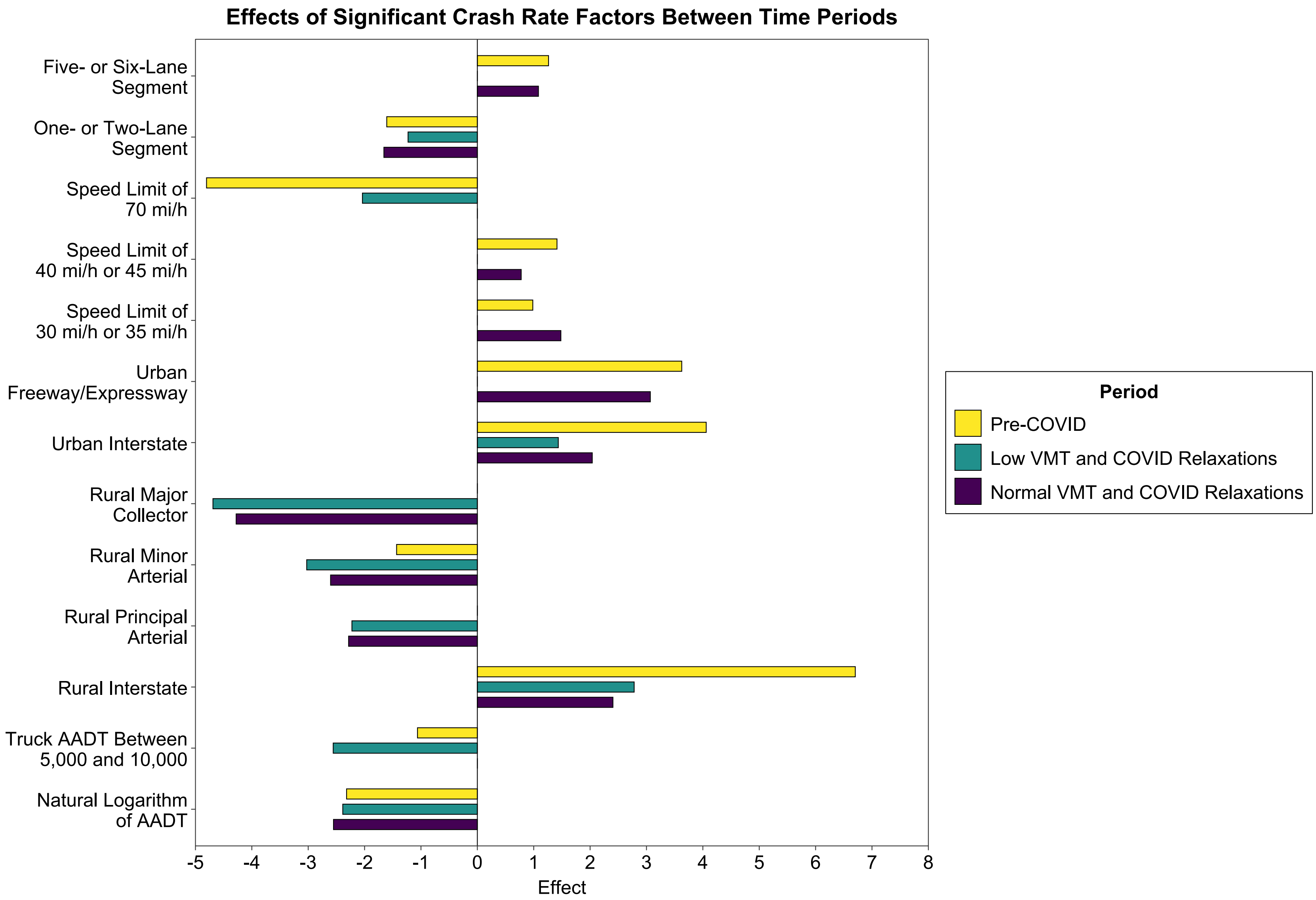

Figure 4.28: Effects of Significant Crash Rate Contributing Factors and Time Period

4.8 INJURY SEVERITY SUMMARY

An overview of the three time period models is given in Table 4.47, while a summary of the injury severity contributing factors is given in Table 4.48. A red arrow indicates the crash characteristic increases the probability of the specific injury severity and a green arrow indicates the crash characteristic decreases the probability of the specific injury severity. A summary of the effects of variables that are in multiple models is shown in Figure 4.29. Note that the plot shows scaled effects, based on the standard deviation of the effects, for illustration purposes.

Of the three time period models, the pre-COVID model had the highest number of significant contributing factors, followed by the normal VMT COVID relaxations period, and lastly the low VMT COVID relaxations period. In total, there were over 100 significant contributing factors across all time period models, five of which were found to have heterogeneous effects through the estimation of random parameters (three of these were in the pre-COVID model). The low VMT COVID relaxations period has the fewest significant contributing factors among the three models, which may be linked to the lower VMT and the resulting decrease in potential conflicts. Table 4.47 and Table 4.48 show that the vast majority of significant contributing factors were unique to a time period model, suggesting (along with the transferability tests) that contributing factors to injury severity were different across the three time periods considered.

Table 4.47: Time Period Model Results Overview

Summary	Pre-COVID	Low VMT and COVID Relaxations	Normal VMT and COVID Relaxations
Months Covered	11.5	11.5	10
Observations	1,025	833	902
From	Apr. 1, 2019	Mar. 16, 2020	Mar. 1, 2021
To	Mar. 15, 2020	Feb. 28, 2021	Dec. 31, 2021
Crash Characteristic Variables			
Possible	16	7	10
Minor	5	7	7
Serious	7	6	9
Fatal	12	10	8
Total Variables	40	30	34
Total Unique Variables	38	29	32

4.8.1 Crash Characteristics with Heterogeneous Effects

Across the three models, just five variables were found to have heterogenous effects on injury severity outcome. In the pre-COVID model, there were three such variables: rural area crashes for serious injury outcomes, if the truck had no trailers for minor injury outcomes, and if traffic signals were present for possible injury outcomes. For rural crashes, previous work has found varying effects of rural locations on severity. For example, some work has found that crashes in rural areas are less likely to result in severe injury outcomes (Uddin and Huynh, 2020), more likely to result in severe injury outcomes (Lemp et al., 2011; Osman et al., 2016; Haq et al., 2021; Yuan et al., 2021), or that the effect of a rural indicator is heterogeneous across crash observations (Uddin and Huynh, 2018). This work is consistent with previous findings. In general, trucks with no trailers lead to less severe crashes (Wei et al., 2017; Wang et al., 2021), which is consistent with this work. The random parameter for the no trailer indicator may be attempting to capture speed at the time of impact or the size of the vehicle involved, both of which can lead to more or less severe injuries depending on typology. Traffic signals have also been shown to, in general, decrease injury severity outcomes (Anderson and Dong, 2017; Behnood and Mannering, 2019; Li et al., 2020; Song and Fan, 2021), but have also been found to increase severity outcomes (Behnood and Al-Bdairi, 2020). Due these varying effects, some work has also found traffic signal variables to have random parameters (Rahimi et al., 2020). The varying effects may be linked to speed at the time of crash or crash-involvement, such as vulnerable road users or small passenger vehicles.

In the low VMT COVID relaxations model, crashes in which two vehicles were going in the same direction and both traveling straight had heterogeneous effects on possible injury outcome. Anderson and Hernandez (2017b) and Xu et al. (2019) found same direction crashes to decrease the likelihood of minor injury outcomes, while Taylor et al. (2018) found such crashes to have heterogeneous effects on injury severity outcome. The resulting severity of two vehicles crashing while both traveling straight in the same direction can be dependent on several factors, often which are not observable in the crash data (e.g., speed at time of impact, the resulting crash type, vehicle size, and others) leading to this parameter being random.

In the normal VMT COVID relaxations model, crashes in which the driver was 45 years to 54 years of age had heterogeneous effects on possible injury outcomes. This could plausibly be due to several factors, including slower perception reaction times, experience driving a truck, distraction (distracted vs. not being distracted, cognitively), and others.

4.8.2 Crash Characteristics with Three or more Instances

Of 72 unique crash characteristics, just six appear more than three times across the three time period models and their severity functions: head-on crashes, inattention, two vehicles going in opposite directions and both traveling straight, reckless driving, and pedestrian involved crashes.

Head-on crashes was the most reoccurring crash characteristic, as head-on crashes are significant contributing factors in five different injury severity functions across all three time periods. In the pre-COVID model, head-on crashes increased the probability of a fatal outcome. Head-on crashes were not a significant contributing factor to serious injury outcomes in any model. For minor injury outcomes, head-on crashes decreased the probability of such crashes in the normal VMT COVID relaxations model. Lastly, head-on crashes was a significant contributing factor to possible injury outcomes in each of the models, where head-on crashes decreased the probability of possible injury outcomes. It appears for this factor, VMT fluctuations nor COVID relaxations play a factor in the effect of head-on crashes on injury severity.

Of the remaining four crash characteristics that have three or more instances, all four reoccur three times, including one characteristic that was found to be a significant contributing factor in each time period. The one characteristic that was a significant contributing factor in each time period was the indicator for if the crash occurred from March to May. In the low VMT COVID relaxations model, crashes that occurred from March to May had a higher probability of a fatal outcome (this coincides with the first several weeks of the COVID relaxations and the reduced VMT due to stay-at-home orders). In the normal VMT COVID relaxations model, crashes that occurred from March to May had a lower probability of a minor injury outcome, and in the pre-COVID model a lower probability of a possible injury outcome.

Regarding driver inattention, there was a higher probability of fatal outcomes in the pre-COVID model, and a higher probability of serious injury outcomes and minor injury outcomes in the normal VMT COVID relaxations model. Reckless driving had similar results, where there was a higher probability of a serious injury outcomes in the normal VMT COVID relaxations model, a higher probability of minor injury outcomes in the low VMT COVID relaxations model, and a lower probability of possible injury outcomes in the pre-COVID model. These results suggest that despite COVID relaxations and fluctuations in VMT, crashes due to the driver recklessly driving are more likely to result in more severe outcomes.

Pedestrian crashes were not a significant contributing factor in the low VMT COVID relaxations model. In the pre-COVID and normal VMT COVID relaxations models, pedestrian crashes had a lower probability of possible and minor injury outcomes, implying a higher probability of more severe outcomes.

4.8.3 Crash Characteristics with Two Instances

Across the three time period models, 20 crash characteristics were significant contributing factors for at least two injury severity outcomes.

Crashes in which safety equipment was not equipped had a higher probability of fatal outcomes in the pre-COVID period and a higher probability of a serious injury outcome in the low VMT COVID relaxations period. Crashes in which the driver was following too closely had a lower higher probability of possible injury outcomes in the pre-COVID period, yet a higher probability of serious injury outcomes in the normal VMT COVID relaxations period. This may be attempting to capture the change in average speed since the pandemic, where higher speeds appear to be the new normal (AAA Foundation for Traffic Safety, 2022; Insurance Institute for Highway Safety, 2022; Wang and Cicchino, 2023), but not necessarily the effect of the COVID relaxations. On this same premise, crashes in which the driver was speeding had a lower probability of possible injury outcomes (implying a higher probability of more severe outcomes) in both COVID relaxations periods (low VMT and normal VMT).

Crashes in which the driver ran off of the roadway had a higher probability of fatal and serious injury outcomes in the pre-COVID period and the low VMT COVID relaxations period, respectively. If the crash occurred in the fall (September to November), there was a higher probability of fatal outcomes in both the pre-COVID period and the normal VMT COVID relaxations period. In Oregon, these months are associated with warmer, dryer conditions that transition to wet, colder conditions; these months are also associated with the start of the school year for schools and universities. This finding may be linked to higher levels of traffic in these two periods, and not necessarily the COVID relaxations.

Crashes in which the driver was not licensed in Oregon had a lower probability of serious injury outcomes in the low VMT COVID relaxations period and a lower probability of minor injury outcomes in the pre-COVID period. Generally, drivers that are unfamiliar with an area tend to drive more cautiously, which lead to less severe crashes should one occur (Anderson and Hernandez, 2017b).

Crashes that occurred on dry roadway surfaces had a lower probability of fatal outcomes in the low VMT COVID period and a higher probability of fatal outcomes in the normal VMT COVID period. Considering both periods include relaxations, and the primary difference is the level of traffic volume, this finding may also be linked to VMT, and not necessarily the COVID relaxations.

Crashes in which the truck had a trailing unit (one, or two or three trailing units) had a higher probability of fatal outcomes in the pre-COVID periods. For serious injury outcomes, there was a higher probability in the low VMT COVID period (two or three trailing units) and a lower probability in the normal VMT COVID period (one trailing unit).

4.8.4 COVID Relaxations Effects

In the holistic model, indicator variables for the time periods considered were used as explanatory variables (see Table 4.41 and Table 4.42).

For fatal outcomes, both indicators suggest there was a higher probability of fatal outcomes in the relaxation periods relative to pre-COVID. However, only the effect of the normal VMT COVID relaxations indicator was statistically significant. For serious injury outcomes, there was a lower probability of serious injury outcomes in the low VMT COVID relaxations period relative to the pre-COVID period and a higher probability of serious injury outcomes in the normal VMT COVID relaxations period relative to the pre-COVID period. Once more, only the effect of the normal VMT COVID relaxations indicator was statistically significant. For minor injury outcomes, the effects of both indicators were statistically significant, and both had a higher probability of minor injury outcomes.

Table 4.48: Summary of Injury Severity Contributing Factors

Variable	Fatal Injury			Serious Injury			Minor Injury			Possible Injury		
	Pre-COVID	Low VMT	Normal VMT	Pre-COVID	Low VMT	Normal VMT	Pre-COVID	Low VMT	Normal VMT	Pre-COVID	Low VMT	Normal VMT
Safety Device												
1 if airbag did not deploy, 0 otherwise	—	—	—	—	—	—	—	—	—	↓	—	—
1 if not equipped, 0 otherwise	↑	—	—	—	↑	—	—	—	—	—	—	—
Crash Type												
1 if angle, 0 otherwise	—	—	—	—	—	↑	—	—	—	↓	—	—
1 if head-on, 0 otherwise	↑	—	—	—	—	—	—	—	↓	↓	↓	↓
1 if rear-end, 0 otherwise	—	—	—	—	—	—	—	—	—	—	—	↑
1 if sideswipe (meeting), 0 otherwise	—	—	—	—	—	—	↑	—	—	↑	—	—
1 if fixed-object, 0 otherwise	—	—	—	—	—	—	—	—	—	↓	—	—
1 if pedestrian, 0 otherwise	—	—	—	—	—	—	—	—	↓	↓	—	↓
1 if overturned, 0 otherwise	—	—	—	—	—	—	—	—	↑	↓	—	—
1 if same direction – both going straight, 0 otherwise	—	—	↓	—	—	—	—	—	—	—	↑	—
1 if opposite direction – both vehicles going straight, 0 otherwise	—	↑	—	↑	—	—	—	↓	—	—	—	—
1 if opposite direction – one vehicle turning left and one vehicle going straight, 0 otherwise	—	—	—	—	—	—	—	—	—	↓	—	—
1 if off-roadway, 0 otherwise	—	—	—	—	—	—	—	↑	—	—	—	—
Crash Cause												
1 if driver followed too closely, 0 otherwise	—	—	—	—	—	↑	—	—	—	↑	—	—
1 if driver drove left of center on two-way road, 0 otherwise	—	—	↑	—	—	—	—	—	—	—	—	—
1 if driver disregarded traffic signal, 0 otherwise	—	—	—	—	—	—	—	—	—	—	—	↓
1 if speed too fast for conditions (not exceeding limit), 0 otherwise	—	↑	—	—	—	—	—	—	—	—	—	—
1 if driving in excess of posted speed, 0 otherwise	—	—	—	—	—	—	—	—	—	—	↓	↓
1 if driver was inattentive, 0 otherwise	↑	—	—	—	—	↑	—	—	↑	—	—	—
1 if driver was recklessly driving, 0 otherwise	—	—	—	—	—	↑	—	↑	—	↓	—	—
1 if driver made improper change of traffic lanes, 0 otherwise	—	—	—	—	—	—	—	—	—	↑	—	—
1 if driver failed to avoid vehicle ahead, 0 otherwise	—	—	—	—	—	—	—	—	—	↑	—	—
1 if driver was carelessly driving, 0 otherwise	—	—	—	—	—	—	—	—	—	↑	—	—
1 if driver ran off the road, 0 otherwise	↑	—	—	—	↑	—	—	—	—	—	—	—
Temporal Characteristics												

Variable	Fatal Injury			Serious Injury			Minor Injury			Possible Injury		
	Pre-COVID	Low VMT	Normal VMT	Pre-COVID	Low VMT	Normal VMT	Pre-COVID	Low VMT	Normal VMT	Pre-COVID	Low VMT	Normal VMT
1 if crash occurred March to May, 0 otherwise	—	↑	—	—	—	—	—	—	↓	↓	—	—
1 if crash occurred June to August, 0 otherwise	—	↑	—	—	—	—	—	—	—	—	—	—
1 if crash occurred September to November, 0 otherwise	↑	—	↑	—	—	—	—	—	—	—	—	—
1 if crash occurred between 5:00 p.m. and 9:00 p.m., 0 otherwise	—	—	—	—	—	—	—	—	—	—	—	↓
1 if crash occurred on a weekday, 0 otherwise	—	—	—	↓	—	—	—	—	—	—	—	—
1 if crash occurred on a weekend, 0 otherwise	—	—	—	—	—	—	—	—	—	—	↓	—
Driver Characteristics												
1 if 35 years to 44 years, 0 otherwise	—	—	—	—	—	—	—	—	—	—	—	↑
1 if 45 years to 54 years, 0 otherwise	—	—	—	—	—	—	—	—	—	—	—	↑
1 if 55 years to 64 years, 0 otherwise	—	↑	—	↑	—	—	—	—	—	—	—	—
1 if 65 years or greater, 0 otherwise	—	—	—	—	—	—	↓	—	—	—	—	—
1 if male, 0 otherwise	—	—	—	—	—	—	—	—	—	—	—	↓
1 if driver not licensed in Oregon, 0 otherwise	—	—	—	—	↓	—	↓	—	—	—	—	—
1 if drive was Oregon resident more than 25 miles from home, 0 otherwise	↑	—	—	—	—	—	—	—	—	—	—	—
1 if not an Oregon resident, 0 otherwise	—	—	—	—	—	—	—	—	↑	—	—	—
1 if driver was not under the influence of marijuana, 0 otherwise	↓	—	—	—	—	—	—	—	—	—	—	—
Roadway and Environmental Characteristics												
1 if roadway classification was rural interstate, 0 otherwise	—	—	↑	—	—	—	—	—	—	—	—	—
1 if roadway classification was rural principal arterial, 0 otherwise	—	↑	—	—	—	—	—	—	—	—	—	—
1 if roadway classification was rural minor arterial, 0 otherwise	—	↑	—	—	—	—	—	—	—	—	—	—
1 if roadway classification was urban interstate, 0 otherwise	—	—	—	—	—	—	—	—	↓	—	—	—

Variable	Fatal Injury			Serious Injury			Minor Injury			Possible Injury		
	Pre-COVID	Low VMT	Normal VMT	Pre-COVID	Low VMT	Normal VMT	Pre-COVID	Low VMT	Normal VMT	Pre-COVID	Low VMT	Normal VMT
1 if roadway classification was urban major collector, 0 otherwise	—	—	—	—	—	—	—	↓	—	—	—	—
1 if roadway classification was urban local, 0 otherwise	—	—	—	—	—	—	↓	—	—	—	—	—
1 if crash occurred in a rural area, 0 otherwise	—	—	—	↑	—	↑	—	—	—	—	—	—
1 if crash occurred during daylight conditions, 0 otherwise	↓	—	—	—	—	—	—	—	—	—	—	—
1 if crash occurred at dark with streetlights, 0 otherwise	—	—	—	—	—	—	—	↓	—	—	—	—
1 if dusk or dawn, 0 otherwise	—	—	—	—	—	↑	—	—	—	—	—	—
1 if roadway had five or six lanes, 0 otherwise	—	—	—	↑	—	—	—	—	—	—	—	—
1 if posted speed limit was 40 mi/h or 45 mi/h, 0 otherwise	↑	—	—	—	—	—	—	—	—	—	↑	—
1 if posted limit was 50 mi/h or 55 mi/h, 0 otherwise	—	—	—	—	—	↑	—	—	—	—	—	—
1 if posted speed limit was 60 mi/h or 65 mi/h, 0 otherwise	—	—	—	—	—	—	—	↓	—	—	—	—
1 if crash occurred on a dry roadway, 0 otherwise	—	↓	↑	—	—	—	—	—	—	—	—	—
1 if crash occurred on a snowy roadway, 0 otherwise	—	—	—	—	—	—	—	—	—	—	—	↑
1 if crash occurred during rainy weather, 0 otherwise	↑	—	—	—	—	—	—	—	—	—	—	—
1 if crash occurred during snowy weather, 0 otherwise	—	—	—	—	—	—	—	—	—	↑	—	—
1 if crash occurred in foggy weather, 0 otherwise	—	—	↑	—	—	—	—	—	—	—	—	—
1 if crash occurred on a grade, 0 otherwise	—	—	↓	—	—	—	—	—	—	—	—	—
1 if crash occurred at an intersection, 0 otherwise	—	—	—	—	↓	—	—	—	—	—	—	—

Variable	Fatal Injury			Serious Injury			Minor Injury			Possible Injury		
	Pre-COVID	Low VMT	Normal VMT	Pre-COVID	Low VMT	Normal VMT	Pre-COVID	Low VMT	Normal VMT	Pre-COVID	Low VMT	Normal VMT
1 if crash occurred in a work zone, 0 otherwise	—	↑	—	—	—	—	—	—	—	—	—	—
1 if no physical barrier between opposing traffic, 0 otherwise	—	—	—	—	—	↓	—	—	—	—	—	—
1 if earth or grass median separating opposing traffic, 0 otherwise	—	—	—	—	—	—	—	↑	—	—	—	—
Traffic Control Device												
1 if traffic signals, 0 otherwise	—	—	—	—	—	—	—	—	—	↑	↑	—
1 if stop sign, 0 otherwise	—	—	—	↑	↑	—	—	—	—	—	—	—
1 if one-way street, 0 otherwise	—	—	↑	—	—	—	—	—	—	—	—	—
1 if median barrier, 0 otherwise	—	—	—	↑	—	—	—	—	—	—	↑	—
Vehicle Characteristics												
1 if truck had no trailers, 0 otherwise	—	↑	—	—	—	—	↓	—	—	—	—	—
1 if truck had one trailing unit, 0 otherwise	↑	—	—	—	—	↓	—	—	—	—	—	—
1 if truck had two or three trailing units, 0 otherwise	↑	—	—	—	↑	—	—	—	—	—	—	—

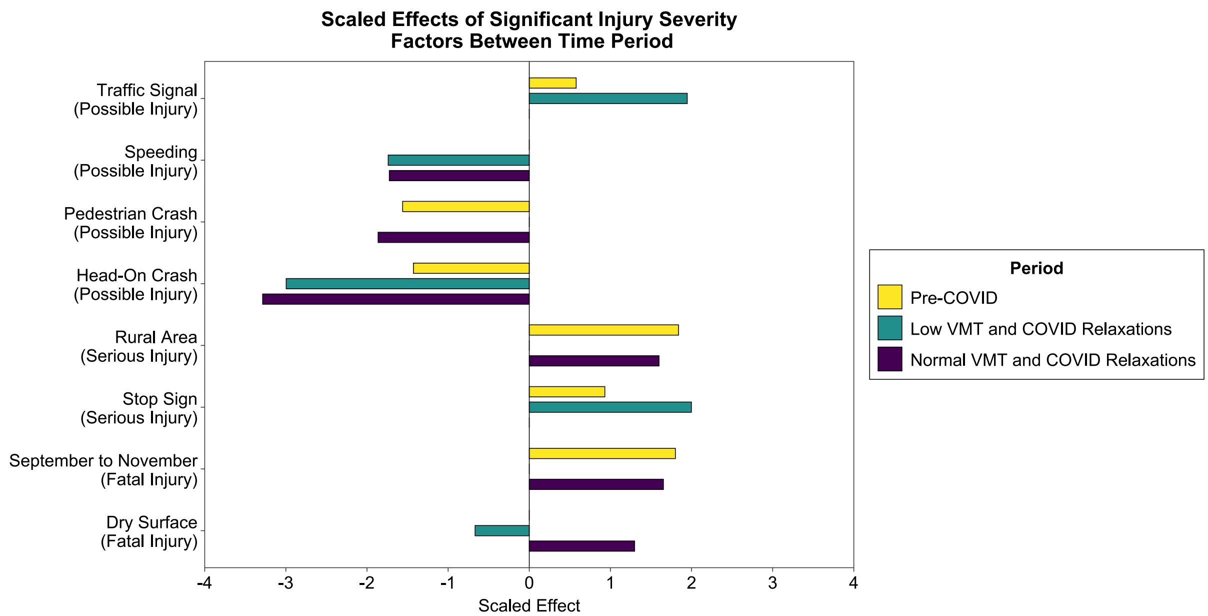

Figure 4.29: Scaled Effects of Significant Injury Severity Factors Between Time Periods

5.0 CONCLUSIONS AND RECOMMENDATIONS

The objective of the current study was to understand freight safety behavior in Oregon due to the trucking regulatory relaxations granted as part of the COVID-19 pandemic relief efforts. To accomplish this, a historical review of trucking regulatory relaxations in the United States was conducted, which included before the pandemic (dating back to 2013) and during the pandemic (through 2022). Through the review, it was determined that trucking regulatory relaxations are granted primarily as part of a State of Emergency declaration, with FMCSA granting relief and state-specific supplemental relief granted as required. Overall, the majority of these declarations before the pandemic were related to severe weather or natural disasters, agriculture, and natural gas.

Oregon, before the pandemic, had only granted relief to help combat wildfires. During the pandemic, Oregon relaxed, in addition to the relaxations granted by FMCSA, hours-of-service, over-dimension and/or overweight restrictions, permitting and/or licensing, and driver-specific elements, such as medical waivers.

Upon review of historical trucking regulatory relaxation trends, a comprehensive data analysis was conducted to understand freight safety behavior in Oregon before and during the pandemic. First, specific time periods were identified that coincided with exposure, as well as ample sample sizes for statistical analysis. Based on vehicle miles traveled, three periods were chosen for analysis: pre-pandemic, the first year of the pandemic when vehicle miles traveled were low, and the following year of the pandemic when vehicle miles traveled began to approach pre-pandemic levels. For both pandemic periods, trucking regulatory relaxations were in effect. After identifying the time periods, a series of data-driven analyses were conducted, including a descriptive analysis and z-test of proportions of crash-related characteristics identified using the Oregon Safety Investigation Manual workbook. Next, a series of freight safety behavior models were developed to describe crash frequency behavior, crash rate behavior, and injury severity behavior for the three time periods considered. In addition to identifying key differences in model specifications, a series of transferability tests were conducted to determine if safety behavior was statistically different between time periods.

The following subchapters summarize the results of the data analyses, followed by recommendations.

5.1 DESCRIPTIVE ANALYSIS

Considering all truck-involved crashes (all injury severities), the majority of significant differences were between the pre-pandemic period and the pandemic period with low VMT (the first year of relaxations, March 16, 2020 to March 2021); thus, suggesting that freight safety behavior may have changed during this time period. There was a significantly higher proportion of fixed-object crashes and single vehicle crashes in the pandemic period with low VMT. This result is likely linked to exposure, as traffic volume across the United States had decreased, on average, by 45% to 55% (Du et al., 2021), where similar reductions were also experienced in Oregon.

Weather related factors, including icy and snow road surface conditions, snowy weather, and smoky weather had significantly higher proportions in the pandemic period with low VMT. These differences were likely linked to the extreme weather events of 2020 and early 2021. In the summer of 2020, Oregon experienced over 1 million acres of wildfires, while in the winter of 2021, an “ice storm” (Hasenstab, 2022; Jones, 2022; Woodworth, 2022).

Crashes that occurred from 12 a.m. to 3 a.m. had a significantly higher proportion in the pandemic period with low VMT, which could be linked to fatigue and/or extended drive times. However, this was not found to be a significant factor in the modeling analysis and cannot be directly linked to the trucking regulatory relaxations. Overall, it appears most differences identified in the descriptive analysis were a result of lessened exposure or extreme weather events and not necessarily linked to the regulatory relaxations.

5.2 CRASH FREQUENCY ANALYSIS

In general, crash frequency behavior followed behavior found in previous work conducted pre-pandemic. This included higher traffic volume leading to increases in expected crash frequency and higher proportion of trucks leading to increases in expected crash frequency. Although these are well-documented factors for crash frequency, the effects of these characteristics were higher in the pandemic periods, particularly the pandemic period with normal VMT levels, suggesting a change in behavior that may be linked to trucking regulatory relaxations. Rural minor arterials were expected to increase crash frequency during the pandemic period with low VMT, while they were expected to decrease crash frequency in the other two periods. With higher speeds observed, as well as less enforcement, this may also be linked to the trucking regulatory relaxations.

In addition to developing three models, which the transferability tests indicated was appropriate, a pooled model was developed that included indicators for the pandemic time periods (shown in Figure 5.1).[7] Results from this model suggest the crash frequency was expected to increase in both the pandemic periods relative to the pre-pandemic period, where both indicators had significant parameters. The low VMT period was significant right at the 90% confidence level, while the normal VMT period was significant with well over 99% confidence. These results suggest that crash frequency was expected to increase during the periods in which the trucking regulatory relaxations were in effect.

[7] Note that the effects shown in Figure 5.1 are scaled, based on the standard deviation of the effects, for illustrative purposes only.

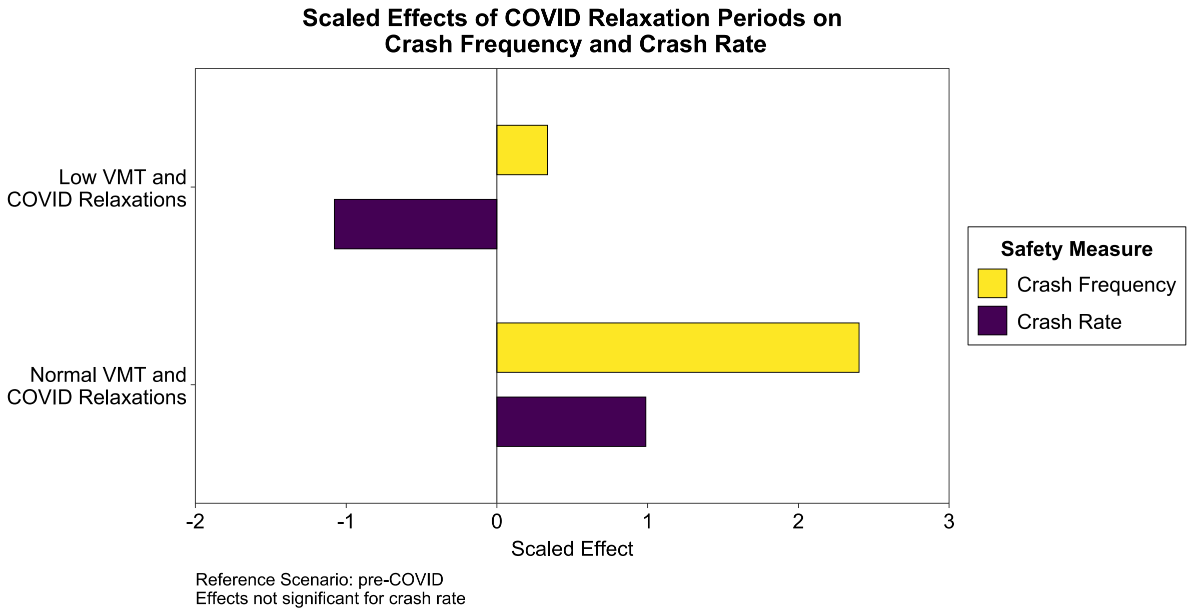

Figure 5.1: Scaled Effects of the COVID Relaxation Periods on Crash Frequency and Crash Rate

5.3 CRASH RATE ANALYSIS

Similar to crash frequency behavior, crash rate behavior followed behavior documented in the literature before the pandemic. A notable difference, however, was the effect of truck traffic. Previous work has shown that as truck traffic increases, crash rate decreases. This work found that as truck traffic increases, so does crash rate. This may be specific to Oregon, as the effects of truck traffic on crash rate were consistent across time periods (higher truck traffic leads to expected increases in crash rate). The magnitude of the effect of truck traffic is notable for medium ranges of truck traffic, where the effect in the low VMT pandemic period is much larger than the pre-pandemic period (larger decrease in crash rate).

Crash rate on urban interstates and rural interstates was expected to increase in all three time periods, but the effect was much larger in the pre-pandemic period. While exposure is likely linked to this result, there may be some other contributing factors that were not captured in the data.

In addition to developing three models, which the transferability tests indicated was appropriate, a pooled model was developed that included indicators for the pandemic time periods (shown in Figure 5.1).[8] Results from this model suggest that crash rate was expected to decrease in the low VMT pandemic period (relative to the pre-pandemic period) and was expected to increase in the normal VMT pandemic period (relative to the pre-pandemic period). The parameters for these indicators were not statistically significant.

[8] Note that the effects shown in Figure 5.1 are scaled, based on the standard deviation of the effects, for illustrative purposes only.

5.4 INJURY SEVERITY ANALYSIS

As with the previous safety behavior, significant injury severity factors tend to follow behavior identified in work before the pandemic. Results from the transferability tests indicated, however, that parameters were not transferable across time periods, suggesting the contributing factors were different between the three periods analyzed. Regardless of how crash data is disaggregated, this is often the case (Behnood and Mannering, 2015, 2019; Al-Bdairi et al., 2020; Islam and Mannering, 2020).

Head-on crashes was the most occurring contributing factor, which explained possible injury (decrease in probability) in all three time periods. It appears VMT fluctuations nor COVID relaxations played a major role, although the effects on probability were greater in the low VMT and normal VMT pandemic periods.

The indicator for if crashes occurred from March to May was also a significant contributing factor in each time period. Results indicated that across time periods, crashes that occurred during these months had either a lower probability of a possible or minor injury outcome, or a higher probability of a fatal outcome. These months are important, as in the low VMT pandemic period, this represents the first several weeks of the COVID relaxations and the reduced VMT due to stay-at-home orders, while for the normal VMT model, it represents the first several weeks back to pre-pandemic levels of traffic with the relaxations still in effect. The results in the low VMT pandemic period may be attempting to capture this. The summer months in the low VMT pandemic period also resulted in a higher probability of a fatal outcome; this, too, may be linked to the trucking relaxations and associated driver behavior (e.g., higher speeds, fatigue).

In addition to developing three models, which the transferability tests indicated was appropriate, a pooled model was developed that included indicators for the pandemic time periods (shown in Figure 5.2).[9] Results from this model suggest that there was a higher probability of fatal injury outcomes in the pandemic periods (relative to the pre-pandemic period), where the effects on probability were comparable. Only the effect of the normal VMT pandemic period was significant, however.

There was a higher probability of minor injury outcomes in the pandemic periods (relative to the pre-pandemic period), with the effect being slightly larger in the normal VMT pandemic period. Both of these effects were statistically significant.

The notable difference is in serious injury outcome probability, as there was a lower probability in the low VMT pandemic period and a higher probability in the normal VMT pandemic period. Only the effects for the normal VMT pandemic period were statistically significant.

These results suggest significant changes in freight injury severity behavior in the normal VMT pandemic period compared to the pre-pandemic period.

[9] Note that the effects shown in Figure 5.2 are scaled, based on the standard deviation of the effects, for illustrative purposes only.

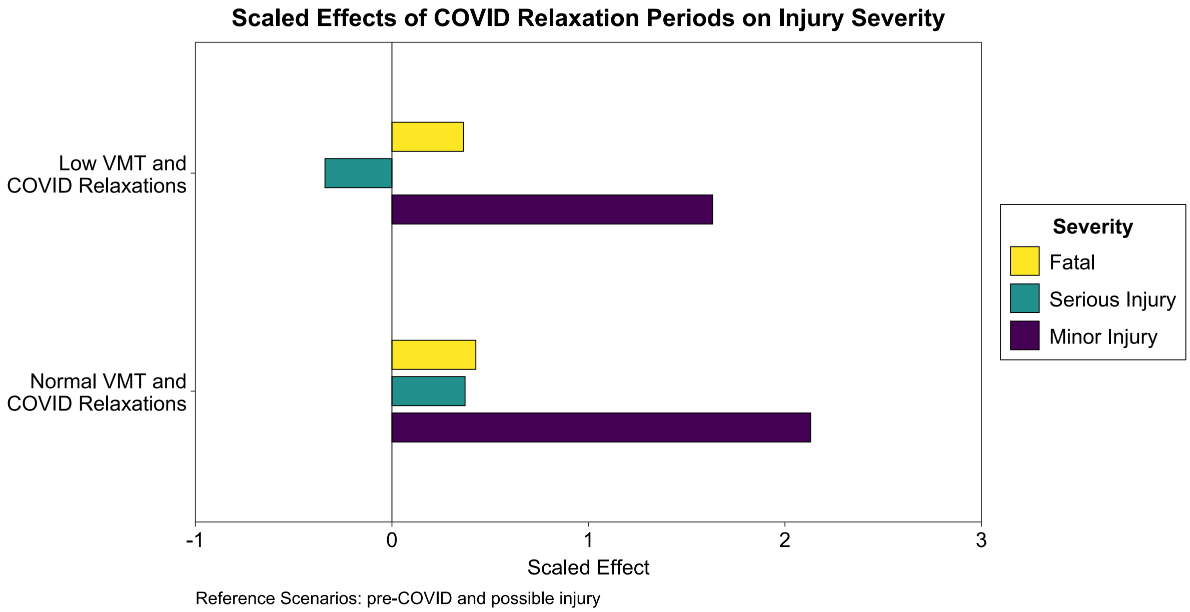

Figure 5.2: Scaled Effects of the COVID Relaxation Periods on Injury Severity

5.5 RECOMMENDATIONS AND FUTURE WORK

5.5.1 Descriptive Analysis

Coding designations in Oregon crash data make it challenging to describe and compare crash characteristics for no injury crashes, as many important crash characteristics are coded as NA for such crashes. As a result, certain crash characteristics are being undercounted and can impact results. This work recommends collecting information on these characteristics for all crashes, including no injury, which will lead to more comprehensive safety analyses. Due to the extreme weather events in 2020 and early 2021, several weather-related crash characteristics were overrepresented and had significantly different proportions. It may be worth studying safety behavior for these periods independently (for both freight and all vehicle crashes) or grouping similar weather events to comprehensively study safety behavior under extreme weather events in Oregon. The descriptive analysis also showed overrepresentation of fixed-object crashes in the low VMT pandemic period, where a study of fixed-object crash behavior only may provide some additional insights. Due to 2021 being the most recent crash data at the time of this work, updating the analysis to include 2022 (or beyond) crash data can provide an additional time period for comparison that would include conditions akin to the pre-pandemic period (i.e., regular VMT levels and no trucking relaxations). From a policy perspective, it can benefit ODOT to be very direct with where relaxations are aimed in the future.

5.5.2 Crash Frequency Analysis and Crash Rate Analysis

The crash frequency analysis and crash rate analysis were limited to the exposure variables present in the crash data and traffic volume. It is recommended to fuse additional data sources with these data to determine if crash frequency or crash rate behavior can be further described. However, some of the roadway-specific characteristics are not updated yearly, making it challenging to match year-to-year data consistently. Additionally, curve information is given in PDF format and not readily available for analysis. A text-mining approach can be applied to gather this information but would require some level of manual checks to ensure it is extracting the data appropriately. It may also be worth fusing weather-specific data to the crash data, which would allow for real-time weather conditions at the time of the crash to be modeled. This work was explanatory in nature, but with additional years of crash data and more complex modeling approaches, a causal-based analysis could be conducted to determine a causal relationship between the implementation of the trucking regulatory relaxations and crash frequency or crash rate behavior. Exploring the feasibility of estimating a crash modification factor for these policy changes can also be assessed. Lastly, this work did not disaggregate the data beyond the time periods. By considering different data disaggregation (e.g., urban vs. rural, daytime vs. nighttime, interstate vs. non-interstate, segment vs. intersection), additional safety behavior insight may be attainable.

5.5.3 Injury Severity Analysis

The injury severity analysis was limited by the coding scheme in Oregon crash data; that is, for many crash characteristics, no injury crashes are coded as NA. This makes it particularly challenging to model injury severity while considering no injury as an outcome. To ensure models were estimable, this work modeled only injury-type crashes. This results in the majority proportion of injury severity types not being described by the models. It is recommended that these crash characteristics be coded for all crashes, including no injury, allowing for a more robust analysis of injury severity behavior. As with the other safety performance measures, further disaggregation of the data may provide some additional insights.

Being that the focus of this safety analysis is on freight and trucking regulatory relaxations, additional information about the truck can be helpful. Linking information to identify the class of the vehicle, gross vehicle weight rating, etc. can be useful explanatory variables to describe injury severity behavior.

Fusing Commerce and Compliance Division crash data with the Oregon crash data has proven difficult, but a project that addresses this could be invaluable for freight-related safety studies given the additional information that would be available. Incorporating real-time speed data, which can provide some information on the speed at the time of impact, can also be helpful; particularly in the pandemic-forward era where vehicle speeds are, on average, much higher.

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